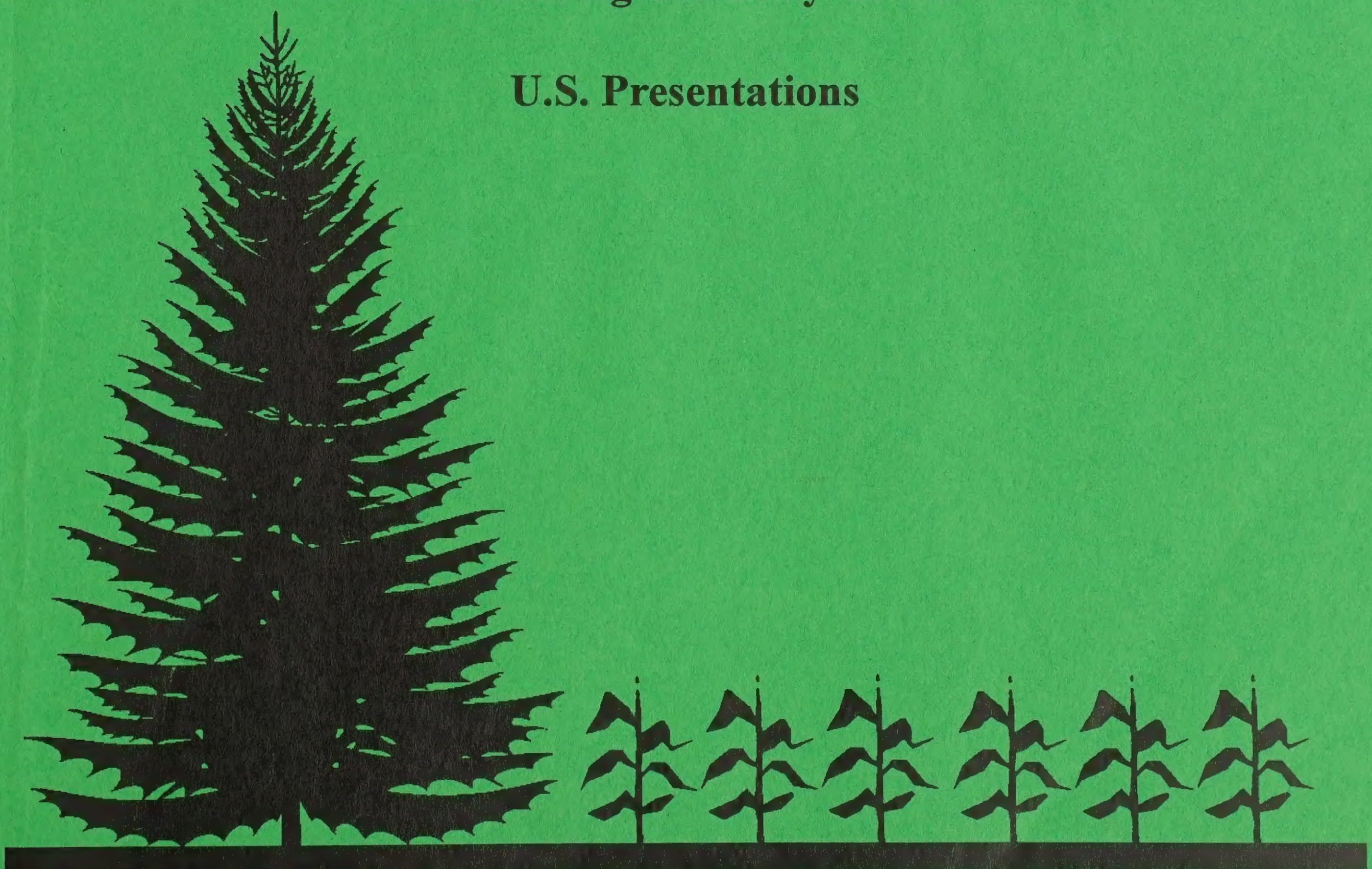
Potential for Agroforestry in Northern Mexico

April 12-15, 1994
Saltillo, Coahuila, Mexico

Workshop jointly sponsored by:
SARH-INFAP
and
USDA Forest Service
Rocky Mountain Forest & Range Experiment Station
National Agroforestry Center

U.S. Presentations



TALLER SOBRE POTENCIALIDADES AGROFORESTALES
EN EL NORTE DE MEXICO
ORGANIZADO EN FORMA CONJUNTA POR:

POTENTIALS FOR AGROFORESTRY
IN NOTHERN MEXICO WORKSHOP.
JOINTLY SPONSORED BY:

SARH
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DEPARTMENT OF AGRICULTURE

USDA FOREST
ROCKY MONTAIN RESEARCH STATION
C.S.A.

EUROHOTEL
SALTILLO, COAHUILA-MEXICO.
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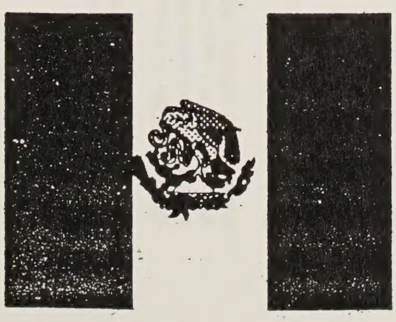

1:00 - 3:00	**LUNCH**
3:00 - 3:20	Windbreak research in the US: technologies, applications and benefits (Mr. Tom Wardle).
3:20 - 3:40	Windbreak research in México (MC. Alberto Dominguez).
3:40 - 4:00	Group discussion of windbreak research needs and opportunities.
4:00 - 4:20	**BREAK**
4:20 - 4:40	Agriculture/water quality issues in the US and riparian buffer systems to protect water quality (Dr. Mike Dosskey). (MSc. Federico de la Garza de la Peña)
4:40 - 5:00	Stress physiology in agroforestry sistems. (Dr. Jesus Vargas Hernández)
5:00	**ADJOURN FOR THE DAY**

WEDNESDAY, April 13
Subject Papers, Continued

8:30 - 8:50	Production agroforestry systems in the US (Dr.Bill Rietveld.)
8:50 - 9:10	Production agroforestry systems in México (Dr. Horacio Villalón.)
9:10 - 9:30	Group discussion of production agroforestry needs and opportunities.
9:30 - 9:50	Resource analysis research to compare the economic, environment, and social benefits of agroforestry options (Dr. Lita Rule).
9:50 - 10:10	Policy analysis of agroforestry options in México (Ing. Evodio Cesar Botello; Ing. Roque Hernández Cardona.)
10:10 - 10:30	Group discussion of resource analysis needs and opportunities.
10:30 - 10:50	**BREAK**
10:50 - 11:10	Biodiversity in agricultural ecosystems: its importance for sustainability (Dr. Mike Dooskey).
11:10 - 11:30	Research in México addressing biodiversity: migrant bird habitat, habitat for other wildlife, interactions between wildlife and agricultural crops (Dr. Enrique Jurado).
11:30 - 11:50	Group discussion on research needs and opportunities to enhance biodiversity.
11:50 - 12:10	Agroecology: agricultural production, environment, and people (Dr. Charles Francis).
12:10 - 12:30	Sustainable Development: opportunities for cooperation (Dr. Charles Francis).
12:30 - 12:50	Group discussion on people as an important component of sustainable systems, and research needs and opportunities for sustainable development.
12:50 - 3:00	**LUNCH**

Facilitated Discussion

3:00 - 3:40	Facilitated group session to identify mutual needs and opportunities. Set stage for small group discussions.
3:40 - 4:00	**BREAK**
4:00 - 4:45	Small group discussions to identify and prioritize specific areas for cooperative agroforestry research.
4:45 - 5:00	Small group reports.
5:00	**ADJOURN FOR THE DAY**
	WORKSHOP ENDS

THURSDAY, April 14

all day	(participation limited to workshop speakers). Work session to agree on what subjet areas have the strongest mutual interest and priority, decide on the number of funding proposals to write, and develop an outline of each one.

FRIDAY, April 15

Keep open to complete proposal development, if needed.

CONTENTS

THE USDA FOREST SERVICE CENTER FOR SEMIARID AGROFORESTRY[1]

W.J. Rietveld[2]

ABSTRACT

The Center for Semiarid Agroforestry (CSA) was authorized by Congress in 1990 to be a partnership of the Research, State and Private Forestry, and International Forestry branches of the USDA Forest Service to provide integrated research, applications, technology transfer, and international exchange for agroforestry. Through its programs, the Center seeks to advance the understanding, acceptance, and use of agroforestry in agricultural ecosystems to provide tree products and enhance agricultural productivity, natural resource conservation, and human environments.

CSA conducts and fosters research to develop improved multipurpose trees, improved agroforestry practices, and integrated production/conservation systems. An extensive technology transfer and applications program provides new/improved technologies and information to natural resource professionals. International technology exchange provides strategic research support for global agroforestry partners and issues, for mutual benefit. The Center works through multidisciplinary and multiagency partnerships with federal and state agencies, universities, and conservation organizations.

INTRODUCTION

The Center for Semiarid Agroforestry (CSA) is a national agroforestry support program authorized by Congress in the 1990 Farm Bill. The Center integrates activities of the Research, State and Private Forestry, and International Forestry branches of the USDA Forest Service in support of agroforestry. CSA is an expansion of a previously existing Research Work Unit at Lincoln, Nebraska, that has a 41-year history of agroforestry research for the Great Plains region. CSA's mission is: "through research and technology transfer, advance the understanding, acceptance, and use of agroforestry in agricultural ecosystems to provide tree products and enhance agricultural productivity, natural resource conservation, and human environments."

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[1]Paper presented at the U.S./Mexico Workshop on "Potentials for Agroforestry in Northern Mexico"; Saltillo, Coahuila, Mexico; April 12-15, 1994.

[2]Program Manager, USDA Forest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822.

CSA pursues its mission through partnerships with federal and state agencies, universities, and conservation organizations. This paper provides an overview of the integrated research, technology transfer, and international exchange activities of CSA.

AGROFORESTRY IN THE UNITED STATES

Agroforestry has existed for many centuries as traditional practices in developing countries. Only in recent years has the term "agroforestry" been used in connection with natural resource management and sustainability. Agroforestry in the United States places more emphasis on conservation agroforestry," to encompass the environmental services and beneficial interactions from trees and shrubs integrated into agricultural land-use systems. Agroforestry is not just "tree farming"; it is a set of practices integrated into agricultural land-use systems that uniquely address multiple issues and provide multiple benefits needed to attain sustainable development within agricultural ecosystems. CSA aims to " re invent" agroforestry to make it relevant to current issues and client needs in the United States.

Specifically, modern agroforestry includes both <u>production agroforestry</u> (growing a tree crop in combination with an agricultural crop to increase the overall productive capacity of the land), and <u>conservation agroforestry</u> (working trees in agro-ecosystems primarily to provide environmental services and multiple resource benefits; tree products are secondary). Trees and shrubs are added to environments that are deficient in woody plants, and benefits are created or enhanced through their introduction. These "working trees" must be the right tree, planted in the right place, in the correct design, for a specific purpose.

Examples of agroforestry practices include: alley cropping; trees in pastures; fine hardwood plantations; fuelwood plantations; windbreaks to protect crops, farmsteads, and livestock; living snowfences to control snow drifting onto roads; livestock havens to shelter livestock in rangelands; riparian buffer strips to filter contaminated runoff water; and wildlife habitat plantings.

These practices include both block and row plantings integrated into agricultural production systems or that have been converted from degraded agricultural lands. There are presently 159 million acres of economically marginal or environmentally sensitive cropland in the United States that may be better suited to agroforestry. This includes, for example, bottomland fields subject to frequent flooding that can be converted to fine hardwood plantations, and highly-erodible or degraded croplands that can be converted to fuelwood plantations or wooded pastures. Fine hardwood and fuelwood plantations are considered agroforestry practices when cropland is converted to an alternative intensively managed tree/crop/livestock system.

Agroforestry practices provide multiple resource benefits because they protect soil and water quality, enhance biodiversity, diversify the

landscape, enhance aesthetic values, and help provide for sustainable development in agroecosystems. For example, riparian buffer systems maintain water quality, provide tree products, and provide critical habitat and corridors for migratory and local wildlife. Such systems may occupy only 5% of the land area of agroecosystems, yet account for over 50% of the biodiversity.

AGROFORESTRY RESEARCH PROGRAMS

To help meet the research needs for agroforestry in semiarid environments, CSA has implemented research in eight subject areas through a combination of In-House Research and Multidisciplinary Research Teams. In-House Research, as the name implies, is research performed by CSA scientists with appropriated funding. Multidisciplinary Team Research is accomplished by teams consisting of CSA, other agency, and university scientists who focus on a subject area of mutual interest, secure outside funding, and perform the research together.

In-House Research

Multipurpose Tree Improvement. Research addresses the problem that presently used tree species and ecotypes are not adequately adapted to withstand the environmental extremes and pests of the semiarid Great Plains. Genetic improvement of multipurpose trees is approached through a combination of long-term field trials, breeding, and utilization of biotechnologies and micropropagation. This research will continually provide improved germplasm for ongoing tree planting, tree breeding, and basic research programs.

Tree Adapt ions to Stress. Environmental stresses reduce survival of planted seedlings, shorten tree longevity, predispose trees to insect and disease attack, and reduce tree effectiveness in agroforestry systems. Research utilizes ecophysiological techniques to identify genetic variation in stress tolerance, identify the important factors (traits) responsible for stress tolerance, and develop methods to efficiently screen for and select ecotypes with improved stress tolerance. This research will provide tools to accelerate tree selection and improvement and systems development.

Tree Defense Systems. This research attempts to understand the mechanisms of tree resistance to insects and diseases. Molecular genetics research utilizes model systems (trees confirmed to be resistant or susceptible to a specific pest) to understand mechanisms of tree defense and their genetic basis. Our research utilizes two approaches. The first approach uses the process of genetic engineering to transfer plant defense genes into selected tree species in order to study and understand mechanisms of resistance and their expression. The second approach involves identifying plant defense genes of ponderosa pine that respond to individual strains of a pathogen that causes western gall rust. The knowledge and tools provided by these studies

will accelerate the development of pest resistant trees for planting and breeding programs.

Tree Health Management. Research addresses the problem that insect and disease pests reduce the effectiveness and shorten the lifespan of trees used in agroforestry. Our approach is to develop integrated pest management strategies through understanding of pest biology and epidemiology, relationships between host tree stress and susceptibility to pests, and natural enemy population dynamics and habitat requirements. Tree health management guidelines developed from this research will reduce pest problems and extend the lifespan and effectiveness of agroforestry systems.

Multi-disciplinary Team Research

Ecological Interactions. Research addresses the problem that, before we can develop guidelines for integrating agroforestry practices in sustainable agricultural land-use systems, we need to first understand and optimize the beneficial ecological interactions that agroforestry contributes to the systems. This Multidisciplinary Research Team seeks to understand and optimize the specific physical (microclimate and soils) and biological (insect/microorganism/bird/ mammal) interactions between agroforestry plantings and agricultural crops. Data will be used to develop models and guidelines for utilizing agroforestry practices to enhance the biodiversity and sustainability of agricultural land-use systems.

Riparian Buffer Systems. Research addresses the problem that agricultural lands are the largest contributor to nonpoint source water pollution, accounting for 70% of impairment of rivers and streams in the Great Plains and the United States. This multidisciplinary team focuses on developing suitable tree/shrub/grass systems to act as a buffer between terrestrial and aquatic ecosystems by filtering, trapping, and degrading, pollutants before they enter the waterway. Research also looks for ways that these systems can provide other valuable multiresource benefits such as wildlife, biodiversity, and tree products. This research will provide guidelines for the design, composition, placement, and management of native and human-made forested riparian buffer systems in semiarid agroecoystems.

Climate Change Impacts. Research addresses the problem that global increases in greenhouse gases are predicted to adversely alter the climate within the agriculturally dependent Great Plains region, with potentially severe impacts on agricultural and agroforest systems. Global change team research helps predict the extremes of adaptation that trees will need to be resilient to predicted climate changes. Research also develops process models of mixed forested and agricultural landscapes to identify and predict the potential effects of changing climate on sustainability of agroecosystems in the Great Plains, as well as the potential of agroforestry to mitigate some of the impacts. Research will also examine the consequences of climate change on

biodiversity in forested riparian systems in the Great Plains.

Integrated Production/Conservation Systems. Research addresses the shared but complex goal of attaining healthy, productive, and sustainable agricultural land-use systems that provide for a diversity of stakeholders and needs. This multidisciplinary ecosytem research team is evaluating alternative integrated tree/crop/livestock systems at different scales (farm to landscape) to determine their economic, ecological, and social benefits. Systems research seeks to provide decision-support models and management tools and strategies needed to effectively integrate agroforestry practices into sustainable agricultural land-use systems.

AGROFORESTRY TECHNOLOGY TRANSFER

Through its cooperative and participative technology transfer program, CSA seeks to advance the understanding, acceptance, and use of agroforestry practices in sustainable agricultural land-use systems. Technology transfer provides the essential bridge between research and practice. CSA technology transfer specialists work with numerous partners and cooperators to communicate new and unused research information and technologies to natural resource professionals.

The target audience for agroforestry technology transfer is natural resource professionals in federal and state agencies, universities, and conservation organizations. These are dedicated professionals who need a reliable source of technical information in order to provide quality technical assistance to landowners. The technology transfer loop is not complete until new technologies are adopted, thus, participation and cooperation are vital to achieve common goals.

CSA approaches technology transfer through a variety of media and activities designed to meet client needs:

Conferences and Workshops - The Center provides leadership for conservation forestry by sponsoring conferences and symposia to assemble knowledge, catalyze new thinking and ideas, identify obstacles, and promote cooperation. Training workshops for practitioners provide new and improved technologies and information in a usable form to assist them in addressing current issues and needs.

Technical Information - Through various media, the Center provides practitioners with the latest technologies and information on agroforestry science and practice. This includes published papers, leaflets, videos, technical guides, providing literature, and publishing "Agroforestry Notes", a numbered series of application notes.

Demonstrations - The Center cost-shares needed demonstrations of proven conservation forestry practices in both rural and community environments, to encourage adoption of new, untried, and innovative technologies.

Applications Projects - The Center cost-shares applications projects with cooperators to evaluate and adapt technologies under local conditions, to pave the way for general adoption.

Assessments - The Center cost-shares assessment projects with cooperators to obtain information needed to advance agroforestry. For example, diagnosing the need and potential for agroforestry in different ecoregions, determining the potential for agroforestry to diversify rural economies, and determining motivational factors to get landowners to plant trees.

Technical Support - The Center provides technical support to natural resource professionals through consultations and participation in roundtable discussions and workshops.

Current Information - The Center publishes "Inside Agroforestry", a quarterly newsletter to keep natural resource professionals informed of current information and events.

Public Information and Education - The Center cooperates with other agencies and organizations in sponsoring a National Arbor Day Foundation program entitled "Conservation Trees for your Farm, Family, and Future" to inform landowners of the benefits of conservation forestry.

AGROFORESTRY INTERNATIONAL -CHANGE

Agroforestry is a unique opportunity for international exchange and cooperation. It addresses urgent economic, environmental, and social issues and needs in both developed and developing countries. Although the specific biophysical, social, and economic conditions are quite different among countries, the <u>issues</u> that agroforestry addresses are quite similar. Specifically: land degradation, soil depletion, biodiversity, economic diversification, pollution, and sustainable development). In spite of large climate zone and other differences, international exchange of agroforestry technologies is very important at the <u>strategic research</u> level -- agroforestry science and technology that is broadly applicable and mutually needed. For example, understanding principles, processes, and mechanisms, and developing methods, techniques, models, systems, and tools. International alliances can readily be developed based on strategic research collaborations combined with adaptive research, performed by local cooperators to evaluate and adapt technologies under local conditions.

Funding for international cooperation in agroforestry is presently very limited. However, the opportunities are unlimited. CSA is developing strategic alliances with appropriate international cooperators for mutual benefit, utilizing available sources of funding, and seeking new sources of funding to attain mutual goals.

CONCLUSION

The Forest Service Center for Semiarid Agroforestry has implemented integrated agroforestry research, technology transfer, and international exchange programs that are presently focused on the Great Plains region. CSA is the only federal program dedicated to agroforestry in the United States and has become a focal point for agroforestry development. However, CSA can only partially meet the national need for agroforestry R6D. Other federal agencies, notably USDA Natural Resource Conservation Service and USDA Agricultural Research Service, have existing R~ efforts to help meet the plant materials and technology needs for agroforestry. Numerous universities are also fully committed to agroforestry research, education, and extension, and represent enormous capability for cooperative agroforestry development. Thus, substantial expertise and institutional capacity exists in the U.S. to develop agroforestry science and practice. The limiting factors are: (1) lack of recognition of the potential of agroforestry, (2) lack of an organized and coordinated effort, and (3) lack of funding for agroforestry.

The expected trend in American agriculture is toward more emphasis on soil and water conservation, multiresource benefits, and sustainability. Thus, agroforestry will receive greater recognition and will play an increasingly larger role in enhancing economic, conservation, environmental, wildlife, and amenity benefits in agroecosystems. Successfully addressing this increasing emphasis on agroforestry will require an even greater reliance on integrated programs, cooperation, and partnerships among agencies, universities, and organizations involved in the development of conservation technologies and information. Agroforestry will become increasingly recognized for its ability to address multiple issues and provide multiple benefits, both domestically and globally.

CENTER FOR SUSTAINABLE AGRICULTURAL SYSTEMS, UNL[1]

Charles Francis[2]

Focus on Centers: In the University of Nebraska as in other organizations, there is a growing awareness that many of the complex challenges facing society will be difficult to address using conventional groups and classical departments. This concern has led to creation of centers of excellence around broader questions, and these are some of the changes we see:

- Nature of questions: we are evolving from a capacity to address simple questions such as what hybrid to plant or what level of nitrogen fertilizer to apply to such complex issues as measuring resource use efficiency, evaluating long-term economic and environmental impact of systems, and calculating multiple outcomes from alternative crop and crop/animal systems.

- Funding or research and education: likewise the funding resources from traditional sources such as s the Fertilizer Institute or a crop commodity board are becoming relatively less important than those from federal agencies, private foundations involved with the environment, and coalitions of funders; we also need to seek a longer-term funding base for research on crop rotations and sustainable systems.

- Reward structure at university: this is evolving from a traditional focus on individual performance to one that encourages team research, multidisciplinary classes and extension activities, and programs that integrate people from outside the system and move across state lines.

Nebraska's Center for Sustainable Agricultural Systems: To answer these complex questions, our university established in 1990 a center to bring focus on sustainable systems and mobilize interest and support around this issue. Our mission is

> to bring together people and resources to promote an agriculture that is efficient, profitable, socially acceptable, and environmentally sustainable for the indefinite future.

This Center currently has a part-time director, full-time Administrative

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[2]Director, Center for Sustainable Agricultural Systems and Professor of Agronomy, East Campus - UNL, Lincoln, NE, USA 68583-0910.

Coordinator and Secretary in offices in the Department of Agronomy. A six-member Faculty Associates group meets monthly to determine policy and decide on specific activities of the Center. A fifteen-person Citizens Advisory Committee meets once or twice each year to hear reports of Center activities and suggest new directions for the future. The Sustainable Agriculture Center is not "bricks and mortar," but rather a group of committed people who are working to implement change in focus throughout the university system.

Research for Future Agricultural Systems: Proponents of a sustainable agriculture anticipate a move by producers toward greater efficiency in use of purchased inputs, then substitution of management and information for inputs, and finally a redesign of systems to take maximum advantage of resource cycling and natural processes (Hill, 1991). Research programs at University of Nebraska have traditionally focused on the first of these steps, and through funding from the Sustainable Agriculture Research and Education Program and other sources have begun to explore the second and third steps. Some of the current research areas supported by the Center include:

- Integrated farm project at experiment station: to better bridge the gaps that exist between departments and disciplines in research, we have established an integrated crop/livestock research and demonstration farm at one of the major experiment stations in Nebraska. Research has concentrated on grazing crop residues in different tillage systems, effects of windbreaks on vegetable production, grazing crop residues with and without windbreaks, contour strip cropping and relay cropping patterns, and compost as a major nutrient source for crops.

- Temporal and spatial diversity in cropping systems: long-term rotations can provide the temporal diversity needed to discourage some insect and weed pests, and in appropriate sequence can provide some of the nutrients needs of component crops. Two-year, four-year, and six-year rotations of crops currently grown in Eastern Nebraska (maize, grain sorghum, soybeans, wheat, alfalfa) are being produced in different sequences with leguminous cover crops added to the system when possible. Spatial diversity is being tested through strip cropping and relay cropping of dissimilar crops in the same field.

- Animal manure as a key nutrient source: concentration of animals in confined areas leads to serious accumulation of manure and the conversion of this resource into a costly and environmentally detrimental waste problem. Composting of manure to stabilize nitrogen and allow loss of much of the moisture can convert this resource into a useful soil additive to replace or reduce chemical fertilizer that is currently imported into the farm. Test strips of manure applied according to soil test results and crop needs are being compared to commercial chemical fertilizer on maize, a principal crop in this area.

- Diversified landscapes and waterways: much of the surface soil and chemical loss occurs during major rainfall events as soil and water move to waterways and into nearby streams, lakes, or ponds. Providing filter strips planted with grass, shrubs, trees, or combinations of these can substantially reduce the flow of both water and soil directly into a watercourse, and these options are being tested in a series of plots at the agricultural experiment station.

Learning from a Systems Perspective: Classical organization of educational curricula around departments and discipline-specific majors and topics has minimized our intellectual focus on the interactions and system dynamics that are essential to a sustainable agriculture. The Center is catalyzing development of seminars, courses, and practical activities that will help to fill this void. A number of interdisciplinary educational activities are now a part of the university curriculum:

- Seminar courses in sustainable systems are taught across disciplines as well as in the animal science department; these are for undergraduates and graduate students who become familiar with the literature on sustainable development and the interconnections among prior experiences and dynamic agricultural systems.

- Nebraska Agri-ecosystem is a first-year course designed to introduce undergraduates to the complexities and interactions in agricultural and food systems in the state; organized around major topic areas, it emphasizes the importance of connections among disciplines in addressing complex system-related challenges.

- Agroecology and Sustainable Development is a new course to be offered to fourth-year students in 1995; it will incorporate agricultural, forestry, animal, and food systems in an integrated manner, drawing on the emerging literature in sustainable agriculture and including people and communities in the development equation.

- Advanced Crop Production is a fourth-year course based on an indepth case study of one Nebraska farm, where students spend several days with the owner and family and evaluate both the crop/livestock system and the decision making process and sustainability of the operation.

- National curriculum for sustainable agriculture is the product of several workshops that brought together farmers, land owners, nonprofit organization specialists, and university faculty to explore available materials and write new units that will contribute to education in sustainable systems; a two-volume set of materials has been published and distributed, and a third volume is in preparation.

- Symposia and workshops have been organized on campus to discuss

planning for the future, designing the next U.S. federal farm legislation, and exploring the impacts of rural policy on the structure of agriculture; numerous seminar speakers have been invited to speak on future agricultural practices, economic impact, and quality of life in rural areas.

Educational Opportunities for Nebraska Farmers: The incorporation of a systems perspective and sustainable development focus on the classroom is only one part of a futuristic educational agenda for the state. We have organized and implemented several educational activities for a road rural audience in Nebraska that has included:

- A citizen's forum on "Designing a Sustainable Future for Food and Agriculture", cosponsored by the League of Women Voters and held on campus for faculty and citizens of the state.

- A bimonthly newsletter that is sent to all Extension Educators, specialists, and faculty; this vehicle describes recent activities and available educational materials on a national level, as well as describing specific educational initiatives in Nebraska.

- A mini-collection of relevant books was purchased and located in the main agricultural library on campus as well as in district research and extension centers around the state; these are accessible to students, faculty, extension educators, and the general public.

- Production and distribution of a brochure entitled "Sustainable Agriculture in Nebraska" to all landowners and farm operators throughout the state; this serves as a directory to faculty and extension specialists who have information on specific areas of interest to farmers and ranchers.

- Workshops on integrated crop management and farm decision making have been conducted in five locations, building on extension specialists' information and farmer panels to describe alternative crops and crop/animal systems for designing a more resource efficient and economically viable agriculture for the future.

- An annual tour of alternative and sustainable practices has been held each year for the past decade, with visits to key experiment station plots as well as farmer fields and enterprises.

Our Sustainable Future is a book series published by University of Nebraska Press that includes specific topics on soil management, crop/animal system design, and crop improvement as well as broad topics such as long-term perspectives on water use and agricultural research alternatives. Title include:

- Ogallala:Water for a Dry Land, by John Opie (1993)
- Building Soils for Better Crops, by Fred Magdoff (1993)
- Agricultural Research Alternatives, by Willie Lockeretz and Molly

Anderson (1993)

- Crop Improvement for Sustainable Agriculture, by B. Callaway and C.Francis (1993)
- Future Harvest: Pesticide Free Farming, by Jim Bender (1994)

Summary & Further Information Resources: these sections have summarized the objectives and the current research and education focus of the Center for Sustainable Agricultural Systems at University of Nebraska. Further information can be obtained by calling or writing to the Center: phone (402) 472-2056, fax (402) 472-7904, e-mail CSAS001@unlvm.unl.edu, mail 220 Keim Hall, University of Nebraska-Lincoln, Lincoln, NE 68583-0949.

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Hill, S.B. 1991. Ecological and psychological prerequisites for the establishment of sustainable prairie agricultural communities. In: Alternative Futures for Prairie Agricultural Communities, J. Martin, editor. Faculty of Extension, U. Alberta, Edmonton.

Hatfield, J.L. and D.L. Karlen, editors. 1994. Sustainable Agriculture Systems. Lewis Publ., Chelsea, Michigan.

SUSTAINABLE AGRICULTURAL LAND USE & INTERDISCIPLINARY RESEARCH[1]

Charles Francis[2]

Historical Land Use Patterns: To evaluate the potential sustainability of land and other resource use by agriculture under current systems it is important to briefly explore the historical perspective of cultures in the past. The current experiment with intensive row crop agriculture and large inputs of fossil fuels is only a recent phenomenon, and it is difficult to objectively assess its long-term viability.

- Prehistorical hunting and gathering systems were sustained for millennia, when human populations were low and both game and undisturbed plant communities were available for food. It is likely that women began to select the best plants and plant them in refuse-rich areas near dwellings where the crops were easily protected and accessible as food for the family. Early crops were grown in the most fertile areas, those most suitable for continuous crop production. Early farmers were generalists, and depended on and worked closely with the natural environment. Their activities were "interdisciplinary" in the broad sense.

- Early cropping and crop/animal systems emerged about 10,000 years ago in the fertile crescent and in other pockets of early communities and civilization. Again, these systems evolved from the previous hunting and gathering activities and were located in the most fertile lands near rivers and in areas with adequate rainfall. Irrigation was an early advancement in agriculture, and the Middle Eastern civilizations that flourished were based in part on addition of water to rain-fed cropping systems. Where these systems extended to extremely dry areas, high rates of evaporation and salinization were well established causes of the demise of some early civilizations. Although their crops were sustained for centuries, many such systems did not survive in the long term.

- Multiple species mixtures predominated for millennia in different parts of the world. In the tropics these consisted of conscious combinations of cereals, legumes, root crops, and other species adapted to the rainfall and temperature regime in a specific location. Examples are the maize/bean/squash system of Central America and the 15-crop mixtures of the humid forest zone of West Africa. Many subsistence farmers still plant these systems to maximize use of limited resources and to minimize risk of failure of any single crop. The multi-storied nature of such crop mixtures in some small way simulates the canopy of natural ecosystems, and the diversity in species spreads the resource

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use over more of the growing season or year. In the temperate zone, farmers in Northern Europe grew mixtures of cereals (barley, rye, wheat, oats) along with some leguminous and other weeds. These mixtures were harvested and used for flour and other products, and the weeds no doubt contributed to fertility as well as some stability in the systems. The most prevalent example of temperate mixtures today is found in grass-legume species combinations in pastures.

- <u>Row crop agriculture</u> is a relatively new system, introduced over the past two hundred years since the invention of pulled implements in the "industrial revolution" in agriculture. The intensive use of chemical fertilizers and pesticides is an even more recent innovation, with most changes happening in the temperate zone and in favored places in the tropics over the past four decades. The long-term sustainability of such systems is difficult to assess, since they are such a new approach to land and resource use. It is certain that we have to take a longer time scale than a year or a decade to evaluate the potential of these fossil fuel intensive systems; most economic or agronomic measures are per year or per season, and do not take into account the changes in soil productivity or estimated long-term availability and cost of fossil fuels needed to sustain the systems and their current levels of productivity.

Resource Use in Agriculture: One important dimension in determining the sustainability of land use is the efficiency of use of land, energy, and other resources in the production process. Although the highly mechanized and capital intensive systems of North America are often cited as "the most productive ever known", this is true only per unit of labor. There are other systems found in other continents that are more efficient in terms of land, capital, energy, water, or other limiting factors. This perspective is important in the assessment of long-term sustainability of land or other key resource use for food production.

Energy use efficiency is highest (up to 20:1 output: input ration) in a modified gathering system in which seed is scattered and crops are later harvested; current applications of this system are only found in a few remote areas such as Papua-New Guinea. Intermediate efficiency (about 10:1) is found in systems such as the tapado system in Central America where brush is cut and allowed to dry and seed of several crops is broadcast into the vegetation. Consistent and lower efficiency (about 4:1 for maize production) is observed in production systems using animal traction, small tractors, or larger tractors; although there is greater labor efficiency with the mechanized and larger units, this is offset in energy terms by their cost of manufacture and fossil fuel use in the field. Water use efficiency is highest in rain-fed cereal systems and lowest in irrigated systems; in Nebraska the water used in the most efficient rain-fed systems is about 3,000 gal/bu (400 kg water/kg maize) and in poorly managed irrigated systems is up to 9,000 gal/bu (1,200 kg water/kg maize). High-technology farms in North America are capital intensive operations that require large initial investment in land, equipment, and infrastructure as well as annual operating loans and interest that are borne by many mid-size and large farms. Labor use

efficiency is definitely high in systems that can produce up to 200 bu/acre (12 ton/ha) of maize or 50 bu/acre (3 ton/ha) of soybean with 1.3 to 2.1 hours/acre (3 to 5 hours/ha) in direct labor input. The sustainability of land use in these high-tech systems depends on what resources are most limiting in the immediate time and location and how available those resources are in the long term. Conventional economic evaluation of efficiency is generally limited to one season or year, and this is not adequate to begin to address the issue of long-term sustainability.

Sustainability of Conventional Farming Systems: Current conventional systems in North America are highly efficient in terms of converting human labor to low-value cereal and legume seed production. Systems have been developed that overcome as much as possible the limitations to productivity in a given location and season by providing additional fertilizer for crop nutrition, chemical pesticides to suppress weeds, insects, and plant pathogens, and irrigation water to supplement rainfall. Labor efficiency has been enhanced by specialization and design of monocultures. This "domination of nature" mentality has the unintended effect of suppressing or changing natural cycles in the field. For example, additional nitrogen applied in place of legumes in a rotation reduces potential for N-fixation; continuous cropping of maize or other cereal removes the potential of natural weed management through crop rotation or allelopathy by other species. In losing some of the potential of the natural environment to produce crops, these current conventional systems have become less sustainable in their productivity.

Potential productivity has also been lost from many of the best lands in North America through soil erosion due to water and wind; it is estimated that half of the topsoil in the maize belt of the U.S. has been lost over the past century or century and a half. Natural regeneration of this productive soil layer can only be measured in fractions of one centimeter per year, and thus the land would have to be fallow for several centuries to regain what has been lost. Long-term rotations of annual row crops with pastures and careful animal grazing or with perennial hay crops can drastically reduce this soil loss. Likewise, more diverse cropping systems such as strip intercropping or relay cropping that maintains a vegetative cover on the land through all or most of the year can reduce soil loss to tolerance levels. The rate of replacement of soil in the Central U.S. is about 5 tons/acre/year (12 tons/ha/year), and this can be achieved by reduced tillage, surface management of residues, and return of all non-harvested grain to the soil. Careful choice of cultural practices can contribute substantially to long-term sustainability of land productivity.

Widespread use of uniform cropping practices and recommendations for pesticides, fertilizers, and irrigation ignores the obvious field-to-field and within field variability that characterizes most agricultural production regions. The larger the fields and the greater the distance from the source of information to the field, the more likely will be the suboptimal use (and frequently the over-application) of production inputs such as fertilizer, water, or chemicals. There is a current

effort to develop satellite-oriented machinery that will keep record of precise locations in each field to monitor yield and adjust subsequent fertilizer applications according to that yield potential. Similar systems may be available to chart weed, insect, and pathogen populations in order to help the producer fine-tune applications of pesticides. This will be an expensive technology that will likely be assessable only to the managers of the largest farms. There are also ways in which the wise manager can use the same principles to fine tune input use without the computer technology. Careful crop scouting, soil testing, and observation of growing crops and harvest weights can provide much of the same information to the operator who works a limited land area and thus has more time to observe the system. Such information intensive management makes the technology available to a wider range of operators, and in the latter case makes this a smaller farm size specific application of efficient technology.

Specialization in cash grain crops or in feeding livestock independent of crop production leads to loss of integration efficiencies of crop/animal production. Production of large quantities of low-value feed grains places the farmer at the mercy of an unpredictable world grain market. A specialized cattle, swine, or poultry feeder often buys all the feed and forward contracts for sale, with a need to make the operation large to get adequate returns to management. In confined animal production the manure is changed from a productive asset to a liability or waste material. Integration efficiencies are gained from crop rotations, grazing animals on low-value fodder or crop residues, pasture-crop rotations, and vertical integration of the crop/animal continuum. These are considered necessary by many to sustain the productivity of the land.

Rational Options for the Future: Sustainable use of land and other resources will require more efficient use of scarce resources, substitution of information and management for fossil fuel based inputs, and careful redesign of future crop and crop/animal systems (see Hill, 1991). Greater efficiency can be achieved by reducing production inputs to the level at which there is no clear economic response, including the total cost to society of producing those products and the off-farm costs of their use, whether intended or not. An example is careful soil testing to determine precise needs for the following crop, and setting of a realistic yield goal to set levels of applied fertilizer. Substitution of information or management for a purchased input is illustrated by use of two-year rotations of maize with one other crop to control rootworm and thus eliminate use of a soil insecticide. Examples of redesign of systems include in-field rotations of cereals and legumes in strip arrangements to minimize erosion and maximize natural control of pests, placement of crops in fields or sequences where they are best adapted and require the least purchased inputs, and integration of crops and animals in one continuous production system.

In addition to rational choice of systems and inputs, there is a vital need for involvement of the community in design of future systems. Many of the off-farm effects of current systems impact the nearby

communities, and conflict arises when the larger society cannot meet its multiple goals without reducing perceived quality of life. Farm size is a key determinant in the health of rural communities, and the entire society should address the need to seek an optimum size for owner-operator farms that maximize involvement and stewardship of all participants in the business. There is a need to address conflicts in the rural/urban interface, and thus an emerging awareness of the importance of involvement of consumers in activities such as community supported agriculture.

Summary and Further Information Resources: These several sections outline changes that would be desirable to convert our present monoculture and specialized agriculture into one that would make more efficient use of natural resources and assure a longer term sustainability of land use. Further information can be found from the references or from the author: phone 402-472-1581, fax 402-472-7904, e-mail CSAS002@unlvm.unl.edu, or 219 Keim Hall, Univ. of Nebraska, Lincoln, NE 68583-0910.

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GENETIC IMPROVEMENT OF TREES FOR AGROFORESTRY SYSTEMS[1]

C. M. Schumann[2]

Tree improvement activities have been underway in the Great Plains region of North America for over 40 years. Because trees are planted in this area primarily to support and enhance agriculture, the traits that are most important (e.g., growth and survival, resistance to stresses and pests) are somewhat different than those that are of interest in timber or wood product producing areas such as the southeastern and pacific northwestern regions of the United States, where growth rate, stem straightness, and lignin content are of primary importance. The approach and scope of tree improvement activities are also different in the Great Plains relative to areas with substantial wood producing industries. Industry supported tree improvement cooperatives in the southeast and northwest have focused intensive efforts on relatively few species, and made remarkable gains. Second and third generation seed orchards are in production, and advanced generation breeding populations well established.

In contrast to this, tree improvement in the Great Plains has been done by a loosely organized group of researchers and forestry professionals from an array of federal and state agencies, and has needed to consider many species (Figure 1). Few tree species are native to the region, so early work included trials of many non-native species. Seed sources of promising species have been tested through provenance trials replicated throughout the Great Plains. Following regular evaluation of these plantings for growth and survival, geographic areas can be identified as recommended collection sites that will yield improved seed for planting in particular locations. Due to limitations on budgets, time, and personnel, this "first-round" of improvement is where our regional projects have stopped for many species. In some cases, however, the importance of a particular species has warranted carrying a project forward to the next level.

One example where this has occurred is in our improvement project on <u>Pinus ponderosa</u>, ponderosa pine. The original provenance tests included 79 sources collected from throughout the eastern edge of the species range (Figure 2); each source represents seed collected from 10-15 trees at a particular location. Seedlings were distributed to cooperators and established at 17 test sites in 1968. Following the 10th-year evaluation, 5 sources were identified as superior in all of the Great

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[2]Research Geneticist, USDA Foorest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822.

Plains plantings: 2 of these sources originated in north central Nebraska, 1 in south central South Dakota, and 2 in central and south eastern Montana. Due to the limited accessibility and availability of seed from the original collection sites and the desire to further describe the genetic variability of ponderosa pine originating from these locations, additional collections were made from these regions in the early 1980's for the purpose of establishing progeny tests. In contrast to the original project, seed from these collections were maintained in 178 single tree lots. Progeny tests were established at 13 locations in the Great Plains. These plantings are being evaluated regularly, and will be thinned and converted to seed orchards as they begin flowering. Seed for future planting stock will originate from these orchards.

Despite the fact that we are now looking to the progeny tests as the source of improved ponderosa pine plant material, the original 1968 provenance tests continue to yield valuable information. These plantings are now mature, and beginning to exhibit many of the problems to which older plantings are prone. Data are now being collected on variable levels of insect infestation (tip moth and Retinia) and disease incidence. Breeding work has been underway for several years to investigate the genetic basis of resistance to a fungal pathogen, Peridermium harknessii. These plantings are also being used for drought tolerance research, which will be discussed in a later presentation by Dr. Bert Cregg.

Information gained from continued research on mature plantations of ponderosa pine and other species, that may have already yielded their primary tree improvement information, will be increasingly important in advancing initial genetic gains. This

Conifers		Hardwoods	
Scots pine	Pinus sylvestris	Eastern cottonwood	Populus deltoides
Austrian pine	P. nigra	Silver maple	Acer saccharinum
Red pine	P. resinosa	Green ash	Fraxinus pennsylvanica
Limber pine	P. flexilis	White ash	F. americana
Jack pine	P. banksiana	Hackberry	Celtis occidentalis
Eastern white pine	P. strobus	Bur oak	Quercus macrocarpa
Ponderosa pine	P. ponderosa	Red oak	Q. rubra
Japanese larch	Larix kaemferi	Sycamore	Platinus occidentalis
Douglas fir	Pseudotsuga menziesii	Black walnut	Juglans nigra
Blue spruce	Picea pugens	Russian olive	Elaeagnus angustifolia
White spruce	P. glauca	Autumn olive	E. umbellata
Eastern red cedar	Juniperus virginiana	Honey locust	Gleditsia triacanthos
Rocky Mountain juniper	J. scopulorum	Black locust	Robinia pseudoacacia
Oriental arborvitae	Thuja orientalis	Chokecherry	Prunus virginiana
		Crab apple	Malus baccata
		American hazel	Corylus comuta
		American plum	Prunus americana
		Amur honeysuckle	Lonicera maackii
		Skunkbush sumac	Rhus triolobata

Figure 1 Species included in tree improvement activities in the Great Plains.

information can be incorporated into more sophisticated tree improvement programs and accelerate development of trees well-suited for the stressful planting sites often encountered in agroforestry systems in the Great Plains.

Figure 2 Geographic sources and test sites for the 79 ponderosa pine provenances included in the 1968 regional tree improvement project.

APPLICATIONS OF BIOTECHNOLOGY AND MICROPROPAGATION FOR AGROFORESTRY[1]

C. M. Schumann[2]

Biotechnology is a rather loosely defined word that has different meanings to different people in different fields. In this presentation I'll consider it to be a set of tools and techniques that allow us to detect and manipulate genetic variation at the DNA level. Closely related and complementary to biotechnology is the discipline of micropropagation. Together these research areas provide powerful approaches for addressing fundamental problems in forest biology. A comprehensive treatment of either area is beyond the scope of this paper; my intent is rather to provide an overview of how we are utilizing several of the techniques in our research at CSA, and provide examples of how we anticipate that these approaches will apply to our long-term goal of tree improvement.

The ability to clonally propagate large numbers of specific genotypes is fundamental to the usefulness of micropropagation and related tissue culture techniques. Trees are often physiologically mature before superior attributes or other interesting phenotypes are expressed, and extremely difficult to propagate through conventional means. Although tissue culture systems must be developed for individual tree species and frequently optimized for particular genotypes within species, once the proper conditions are established the potential for multiplying a desirable genotype is virtually unlimited. Tissue culture techniques can be scaled up to commercial levels to directly produce planting stock of valuable genotypes. More frequently in forestry, however, they are used on a smaller scale for research purposes. At CSA we are working toward developing and improving micropropagation systems for ponderosa pine (Pinus ponderosa), Douglas fir (Pseudotsuga menzessii), green ash (Fraxinus pennsylvanica), and poplar (Populus sp.).

An efficient micropropagation system is a desirable and frequently essential prerequisite for other biotechnological investigations. This is certainly the case for studies utilizing transformation technology, such as our work at CSA on introduced defense genes in poplar. This work involves studying expression and function of a proteinase inhibitor II gene (pin2) from potato that has been cloned and transferred to hybrid poplar. Pin2 is believed to interfere with digestive processes of insect pests and pathogens, thus slowing their development and/or reproduction. It is thought that resistance conferred by mechanisms such as this will

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[2]Research Geneticist, USDA Forest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822.

be stable over time because they exert only moderate selective pressures on pests. Techniques such as polymerase chain reaction (PCR) are used to confirm the presence of the pin2 gene in poplar, and enzyme-linked immunosorbant assay (ELISA) and western blotting are used to detect and study its expression.

Biotechnological approaches are also being used at CSA to study native defense gene systems in trees. The model system for this work is the pathogen *Peridermium harknessii*, which causes western gall rust, and the host ponderosa pine. Classical genetics and pathology approaches are being used to understand variation in both host and pathogen phenotypes; this work includes developing full-sib seedling families and testing them under controlled conditions for reaction against various pathogen isolates. Complementing this research is a molecular genetic approach in which we are investigating pathogen induced genes in a resistant host. Through pathogen challenge experiments and cDNA library screening we hope to gain insight into molecular mechanisms involved in resistance.

A long-term benefit of this and other molecular research might be the development of DNA-based markers that would allow early selection in tree improvement programs. Molecular mapping projects are underway for a number of tree species, and early results indicate that even seemingly complex physiological traits are under relatively simple genetic control; thus marker assisted selection holds great promise for future tree improvement activities. Molecular markers will also prove useful in identifying superior genotypes and maintaining clonal integrity in vegetatively propagated species.

In closing, recent developments in biotechnology and the related field of micropropagation are providing new tools for forestry research and tree improvement applications. These tools have great potential for accelerating development of improved trees for agroforestry, but will be most effective when used to enhance on-going tree improvement programs, not replace them.

APPLICATIONS OF ECOPHYSIOLOGY TECHNIQUES TO ACCELERATE SCREENING SELECTION OF DROUGHT RESISTANT TREES FOR AGROFORESTRY[1]

Bert M. Cregg[2]

INTRODUCTION

The increase in our knowledge of stress physiology and stress resistance in woody plants over the past decades has prompted many authors to propose using morpho-physiological traits to screen for improved drought tolerance in forest trees (VanBuijtenen et al. 1976, Tyree 1976, Gregg 1994a). The opportunity for ecophysiological-based screening is especially apparent in selecting trees for conservation agroforestry, where the ability of trees to survive in harsh environments is as important as height growth or fiber production. In order to select stress tolerant trees for conservation forestry we must first identify and understand the traits that convey the stress tolerance. Secondly, we must determine the extent of genetic variation in those traits. Additional factors that need to be considered in selecting trees for improved stress tolerance are; the nature and extent of genotype x environment interaction (G x E) in stress tolerance traits and the juvenile/mature correlation of stress tolerance traits. In the following paper I will discuss these factors as they relate to our current program to apply physiological criteria to improve the drought tolerance of trees for conservation forestry. Additionally, I will refer to recent studies from the literature on tree species of importance in the central Plains of North America.

MECHANISMS OF DROUGHT TOLERANCE

The first prerequisite in selecting trees for improved drought tolerance is to understand the traits responsible. In general, drought tolerance is the capacity of a plant to survive or grow during periods of little or no precipitation. Jones et al. (1981) classify drought tolerance mechanisms based on the more detailed classification of Levitt (1972). Drought tolerance at high tissue water potential, often referred to as drought stress avoidance, involves morphological and physiological mechanisms related to either maintenance of water uptake or reduction of water loss. Drought tolerance at low tissue water potential or drought stress tolerance involves the maintenance of physiological processes as plant water potential (ψ) declines. Both forms of drought tolerance have been demonstrated in tree species. Further, genotypic variation in drought tolerance mechanisms has been found for a number of tree

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[2]Research Plant Physiologist, USDA Forest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822.

species. Examples of genotypic variation in each type of mechanism are discussed below.

DROUGHT TOLERANCE AT HIGH TISSUE WATER POTENTIAL (DROUGHT STRESS AVOIDANCE)

Adaptations which increase water uptake or reduce water loss may increase the ability of trees to tolerate drought (VanBuijtenen et al. 1976). The primary examples of this type of drought tolerance trait Include low stomatal density, low specific leaf area, relatively high allocation of biomass to roots, and low rates of gas exchange, particularly transpiration.

In a recent examination of needle morphology of 25-year-old ponderosa pine (Pinus ponderosa Dougl. ex Laws.) I found that needles from trees of a South Dakota seed source had significantly lower stomatal density than needles from trees from a Montana and an Arizona seed source (Cregg 1993). Genetic variation in leaf morphology has been observed for a number of other species important in the Great Plains including Gercis canadensis L. (Abrams 1988), Juniperus virginiana, J. scopulorum (Cregg 1992), and Fraxinus pennsylvanica (Abrams et al. 1990). Surface-to-volume ratios of foliage from four juniper families indicated that the relative amount of transpiring surface to leaf volume can differ significantly among genotypes (Gregg 1992). Abrams et al. (1990) found that specific leaf area and stomatal density decreased in sources of Fraxinus pennsylvanica along a longitudinal and decreasing precipitation gradient from New York to South Dakota. Cercis canadensis seedlings from a xeric Kansas prairie source had significantly lower specific leaf areas than seedlings from a more mesic Indiana source (Abrams 1988).

In general, physiological adaptations to tolerate drought at high (ψ) are related to water conservation through low stomatal conductance (g_s) or rapid stomatal closure under stress (Jones et al. 1981). Such adaptations have been found for a number of tree species (Knauf and Bilan 1974, Bennett and Rook 1978, Blake et al. 1984). Seasonal gas exchange patterns of 25-year-old ponderosa pine indicated that trees from a South Dakota source had relatively low rates of net photosynthesis early in the growing season when soil moisture was high but were able to maintain higher rates later in the growing season as soil moisture declined (Cregg 1993). Bennett and Rook (1978) observed that the transpiration rate (E_t) of a Pinus radiata D. Don clone that survived poorly in the field was twice that of a clone that had high field survival. Bilan et al. (1977) found that E_t of loblolly pine (Pinus taeda L.) from the xeric "lost pines" source was significantly lower than seedlings from a more mesic east Texas source at the end of a seven day dry down cycle. Differences in g_s of progeny from crosses of coastal and interior varieties of ponderosa pine (ponderosa x scopulorum) and coastal varieties (ponderosa x ponderosa) were highly significant ($p < 0.0001$) (Monson and Grant 1989). Lower g_s and E_t resulted in increased water use efficiency in the ponderosa X scopulorum progeny.

In addition to leaf morphology and gas exchange characteristics, allocation to roots may play a large role in conveying drought tolerance in trees species. I observed significant genotypic variation in allocation patterns to roots and shoots in ponderosa pine seed sources that differed in their ability to survive imposed drought (Cregg 1994b). This study indicated that seedlings which had the highest capacity to survive drought were intermediate in their allocation to roots and shoots, while those seed sources that succumbed the fastest during drought allocated relatively high amounts of biomass to shoots versus roots or vice versa. Lopushinsky and Beebe (1976) observed that ponderosa pine and Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seedlings with relatively large root systems had greater survival when out-planted than seedlings of the same species with similar sized shoots but smaller roots. Mortality due to drought was significantly ($P \leq 0.05$) correlated with increased shoot growth relative to root growth in a range-wide study of 43 provenances of Abies grandis (Dougl.) Lindl. (Scholz and Stephan 1982). Overall, drought survival was highest from A. grandis sources from xeric locations in eastern Oregon and eastern Washington and lowest from mesic sources west of the Cascade range. In loblolly pine, allocation to roots was generally greater for provenances from relative xeric sites as compared to more mesic sources (Bongarten and Teskey 1987).

DROUGHT TOLERANCE AT HIGH TISSUE WATER POTENTIAL (DROUGHT STRESS TOLERANCE)

Drought tolerance at low is generally indicated by maintenance of g_s, E_t, and other physiological processes as ψ declines. Drought tolerance at low ψ is often achieved by osmotic adjustment, whereby positive turgor pressure is maintained at lower ψ than without adjustment. The benefits of osmotic adjustment to the plant are: 1, maintenance of cell elongation; 2, maintenance of stomatal opening; 3, maintenance of photosynthesis; 4, survival of dehydration; and 5, exploration of greater soil volume for water (Turner and Jones 1980). Recently, several studies have documented genotypic differences in osmotic adjustment and maintenance of physiological processes under drought.

Abrams et al. (1990) observed that g_s and net photosynthesis of Fraxinus pennsylvanica seedlings from a xeric site in South Dakota were higher than that of seedlings from a more mesic site in New York. Seedlings from South Dakota also were found to have lower osmotic potential ($\psi_{\%}$) at full and zero turgor than the New York source. Abrams (1988) found a similar trend in Gercis canadensis, as seedlings from a xeric Kansas site had significantly lower $\psi_{\%}$ than seedlings from a more mesic Indiana source. Additionally, leaf $\psi_{\%}$ was determined to be significantly different among three species of Quercus examined by Parker and Pallardy (1988). They observed that leaf $\psi_{\%}$ of Q. stellata Wang. was consistently lower than that of Q. alba L. or Q. macrocarpa Michx. Parker and Pallardy (1985) also observed significant differences in leaf and root osmotic adjustment among several sources of Juglans nigra L. Genotypes with a relatively high capacity to osmotically adjust (i.e., decrease $\psi_{\%}$ in response to drought stress) may be better able to maintain

photosynthesis and other physiological processes during drought than those types which lack the ability to osmotically adjust. Thus, it is possible that the ability to osmotically adjust during drought may serve as a criterion for drought tolerance selection programs.

In addition to low ψ_{π}, the ability to maintain membrane integrity as ψ declines may also be a key trait to identify drought tolerant types. For example, Kuhns et al. (1993) found that seed sources of *Quercus macrocarpa* differed in the amount of injury to leaf cell membranes as ψ declined. In particular, they observed that membrane injury increased more rapidly as (ψ) declined for *Q. macrocarpa* seedlings from a Nebraska source than seedlings from a Texas seed source, suggesting that drought stress tolerance was greater for the Nebraska source than for the Texas source.

ADDITIONAL CONSIDERATIONS

While it is important for stress physiologists to identify and understand the key mechanisms responsible for drought tolerance and the extent of genetic variation in these traits, there are several other factors that should be considered in designing research to screen for drought tolerance. These factors include the type of genetic variation, the correlation between juvenile and mature trees and genotype x environment interaction.

In general, most of the examinations of genetic variation in physiological traits have been conducted on plant materials from widely divergent populations. Because physiological measurements are intensive in terms of labor and equipment, it is difficult to sample a large number of populations, therefore investigators frequently sample the extremes of a species range. It is important to note however, that genetic variation between families within a population or even between individuals within a family may be just as large as that between populations. We found that the variation in ψ_{π}, among open-pollinated families within two widely divergent seed sources of ponderosa pine was larger than the variation between the two sources (Olivas-Garcia and Gregg 1994). Similarly, family variation in survival of ponderosa pine seedlings under imposed drought was often as large as the variation between sources (Cregg 1994b). Vargas-Hernandez et al. (1986) observed wide inter- and intra-specific differences in drought tolerance characteristics among seedlings of *Pinus greggii* Engelm., *P. leiophylla* Schl. *et* Cham , *P. montezumae* Lamb. and *P. patula* Schl. *et.* Lamb. These studies suggest that an appropriate strategy for selecting genotypes for drought tolerance studies might be a combined progeny-provenance test (Wright 1976, pp 262-263) which allow evaluation of both inter- and intra-population variation in drought tolerance.

The correlation of traits between juvenile and mature trees is also a key factor in determining the ability to select trees for improved drought tolerance. For example, if the juvenile/mature correlation is high then trees may be selected at a young age with the confidence that they will continue to display the trait when mature. If, in contrast,

the juvenile/mature correlation is low, then early selection for the desired trait may not be possible. However, the nature and extent of differences in stress physiology between juvenile and mature trees has not been widely studied and is poorly understood (Cregg et al. 1989). I found relatively little variation in stomatal density of ponderosa pine seedlings from South Dakota, New Mexico, and Montana; while stomatal density of mature trees from the same sources differed significantly. Knauf and Bilan (1974), in contrast, found significant differences in stomatal density and other needle characteristics in two-year-old seedlings of loblolly pine from two diverse seed origins. However, they did not observe significant differences between the same two sources in needles from 16-year-old trees. Donovan and Ehleringer (1991) found significant differences In ecophysiological traits such as water-use efficiency and net photosynthetic rate between juvenile and mature plants of several woody species including Acer negundo L. and Salix exigua Nutt.

The interaction of genotype and environment (G x E) also has profound implications for selecting trees for stress tolerance. If, for example, G x E interaction is small then genotypes which express a drought tolerance trait in one environment (i.e. a greenhouse) will express the trait in other environments (i.e. the field). Comstock and Ehleringer (1993) found such a relationship in a study of the water-use efficiency of common bean (Phaseolus vulgaris L.) using carbon isotope discrimination. They observed a strong correlation (R =0.79) between the carbon isotope discrimination of bean genotypes in the greenhouse and in the field, indicating little G x E interaction. In contrast, we found significant G x E interaction for needle morphology traits of 25-year-old ponderosa pine trees from various seed sources grown in eastern Nebraska and central Oklahoma (Spears, Hennessey, and Cregg; unpublished data).

SUMMARY

In general, drought hardiness of trees is related to drought tolerance at high ψ or drought tolerance at low ψ. Our recent research and related studies in the literature provide ample evidence of genetic variation for both types of drought tolerance mechanisms. This indicates that the drought hardiness of certain species may be improved though selection and breeding for these traits. However, we need to develop a greater understanding of the nature and extent of genetic variation in drought tolerance traits in woody plants in order to efficiently and effectively increase the drought tolerance of trees agroforestry.

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POTENTIAL OF CARBON ISOTOPE DISCRIMINATION IN SCREENING DROUGHT RESISTANT TREES FOR AGROFORESTRY[1]

J. Miguel Olivas-Garcia[2]

INTRODUCTION

It is known that the availability of water is one of the main factors limiting productivity in semiarid areas. Because of that, trees used for forest plantations and/or agroforestry systems, must be drought tolerant in order to succeed under these conditions.

The concept of water use efficiency (WUE) is a key tool to select genotypes adapted to drought conditions. In agronomy, water use efficiency is defined as "the ratio of dry matter produced by photosynthesis to the water consumed in evapotranspiration" (Rosenberg et al 1983). However, in physiological studies it is more common to use this concept as the ratio of photosynthesis to transpiration, sometimes referred to as "instantaneous" water use efficiency (Sulzer et al 1993).

Using portable gas exchange instruments we can examine variation in net assimilation rate (A), leaf conductance to water vapor (g_{wv}) , transpiration (E) and instantaneous water use efficiency (WUE) Collecting data with gas exchange instruments in trees usually is not easy. In addition, this equipment determines WUE of the plant only at the time when the measurement is taken. Carbon isotope discrimination (Δ) analysis may be a better technique to identify WUE in trees because these measurements are integrated over the development of a tissue being analyzed (Johnson et al. 1990).

In this paper I will review the correlation between WUE and carbon isotope discrimination, and the potential of using Δ analysis as a technique to select drought resistant trees for agroforestry systems.

WATER USE EFFICIENCY AND CARBON ISOTOPE DISCRIMINATION

Theory of carbon isotone discrimination

The two naturally occurring stable isotopes of carbon in the atmosphere are ^{12}C and ^{13}C, which comprise 98.89 and 1.11% of the total carbon in

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[1]Paper presented at the U.S./Mexico Workshop on "Potentials for Agroforestry in Northern Mexico"; Saltillo, Coahuila, Mexico; April 12-15, 1994.

[2]Research Graduate Assistant, USDA Forest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822.

the atmosphere, respectively (Svejcar 1990). The ^{13}C to ^{12}C ratio in plant tissue is commonly less than that in the atmosphere, indicating that carbon isotope discrimination occurs in the incorporation of CO_2 into plant biomass (Farquhar et al 1989). O'Leary (1981) indicated that G_3 plant species discriminate against $^{13}CO_2$ during photosynthesis to a greater extent than do C_4 plant species.

Usually C_3 plants have a $^{13}C/^{12}C$ ratio about 20‰ (per mil) less than that of the atmosphere while C_4 plants have a ratio which is lower than the atmosphere by about 10‰ (Farquhar 1982). These differences exist because phosphoenolpyruvate (PEP) carboxylase. the primary carboxylating enzyme in C_4 plants, discriminates less against ^{13}C than Ribulose biphosphate carboxylase-oxygenase (Rubisco) which fixes CO_2 in C_3 species (Farquhar et al 1989).

The isotopic ratio of ^{13}C to ^{12}C (δ) in C_3 plants varies mainly due to discrimination in diffusion and enzymatic processes. Diffusivity of $^{13}CO_2$, across the stomatal pathway is lower than that of $^{12}CO_2$. In addition, there is a differentiation in reaction of $^{12}CO_2$ and $^{13}CO_2$ with Rubisco. In both cases, the processes discriminate against $^{13}CO_2$ which is the heavier isotope (Farquhar et al. 1989).

It has been stated that the amount of isotopic discrimination occurring in plants may be estimated from the isotopic ratio of the plant (δ_p) and the air (δ_a) as:
$\Delta=(\delta_a-\delta_p)/(1+\delta_p)$.

The amount of discrimination and the resulting isotopic composition of the plant tissue are determined by the ratio of intercellular to atmospheric partial pressure of CO_2 (p_i/p_a,) when the tissue is assimilated: Δ-a+(b-a)(p_i/p_a) where a is the fractionation occurring due to diffusion in air (4.4‰, a theoretical value that has not been confirmed experimentally). b is the net fractionation caused by carboxylation (discrimination by Rubisco -27‰) and p_a and p_i are the ambient and intercellular partial pressures of CO_2 respectively (Farquhar et Bal 1989). From this relationship Farquhar et al (1989) argue that Δ may be used as a surrogate measure of p_i/p_a in selecting for improved WUE in crop breeding programs.

Correlation between water use efficiency and carbon isotone discrimination in crops

Carbon isotope discrimination has been used as a selection criteria to improve water use efficiency in a large number of crops. Ehleringer et al (1991) analyzed Δ as an indicator of WUE and transpiration efficiency (water use efficiency) on a long term base in various genetic lines of common beans (*Phaseolus vulgaris* L.) from Central, South and North America. They found that Δ was significantly and negatively correlated with WUE and that on average, lines developed for Central and South America have higher WUE (0.63 vs. 0.57 mmol^{-1}, respectively) and lower Δ values (21.07 vs. 21.51‰, respectively) than lines developed for North America.

In a study under greenhouse conditions with 12 cultivars of common bean, it was found that Δ, measured on leaf tissue, was positively correlated with maximum rate of net photosynthesis (A_{max}) and conductance (g_{max}) (Comstock and Ehleringer 1993). These results indicate that 4 is higher as conductance increases.

Farquhar and Richards (1984) analyzed Δ in several wheat genotypes and found that variation in Δ among and between genotypes was correlated with WUE. They concluded that Δ analysis may be a useful tool in selection for improved WUE in breeding programs for C_3 species.

In another study with 14 wheat genotypes, Condon et al (1990) measured Δ in plant dry matter, transpiration efficiency (WUE) and the ratio of intercellular to atmospheric partial pressure of CO_2 (p_i/p_a,) in leaves under glasshouse conditions. Carbon isotope discrimination measured in dry matter and p_i/p_a measured in flag leaves were positively correlated and the variation among genotypes in p_i/p_a was attributed to similar variation in leaf conductance and in photosynthetic capacity. They also found a negative correlation between Δ and WUE under both, well watered and terminally water-stressed conditions. Condon et al. (1990) concluded that it is possible to analyze Δ under well watered conditions to improve WE in wheat.

It has been suggested that the $^{13}C/^{12}C$ ratio may be different for different tissue in the plant source; however, Hubick et al. (1986) found that for various genotypes of peanut (Arachis), the Δ values of stems, roots and pods were highly correlated with and therefore well represented by the Δ of the leaves. In addition, they found that Δ of leaves and WUE were strongly correlated (r--0.81). In this study they concluded that although the link between Δ and WUE is not direct, the strong correlation between them suggests that other factors do not interfere greatly. Hubick and Farquhar (1989) also found that for 12 barley cultivars under various ambient temperatures, vapor pressure deficits, and soil moisture conditions, there were differences in Δ among plant parts but correlations were large between whole plant WUE and Δ of any of the plant parts.

In a study with peanut, Wright et al (1994) found that WE is negatively correlated with Δ and concluded that Δ analysis is a useful trait for selecting peanut genotypes with improved WUE under drought conditions in the field. Moreover, they found a strong negative correlation between WUE and specific leaf area (SLA) and between Δ and SLA. Correlation of SLA to Δ was analyzed in the same genotypes by Nageswara Rao et al (1994) end they concluded that SLA can be used as a surrogate for Δ in peanut. If this correlation holds true for other plant species, SLA could be used as a rapid and inexpensive selection index for high WUE where facility for Δ analysis is not available.

The relation of Δ to WUE has also been widely studied in crested wheatgrass [Agropyron desertorum (Fisher ex Link) Schultes]. Read et al (1992) found that WUE is significantly correlated with both leaf Δ and shoot Δ. In addition, they found that Δ and the ratio of intercellular

CO_2 concentration to atmospheric CO_2 concentration (C_iC_a,) are positively correlated. In this species Read et al. (1993) also found that Δ and stomatal conductance (g_s) are positively correlated.

Carbon isotope discrimination in trees

Although Δ has been widely studied in crops, relatively few studies have been conducted in trees. The studies which have examined Δ in trees suggest that this technique may be also useful to identify variation in WUE.

Zhang et al. (1993) conducted a study to analyze the genetic differentiation in Δ and gas exchange in Pseudotsuga menziesii. They found that Δ analyzed in leaves is positively correlated with C_iC_a and conductance, and negatively correlated with instantaneous WUE.

One of the advantages of analyzing Δ in trees growing in temperate climates is that it is possible to analyze Δ in annual rings of the stem. Leavit (1993) found that for Pinus strobus and Acer saccharinum the seasonal variation in $^{13}C/^{12}C$ ratio within tree rings coincided with similar changes in leaves. In this study Leavit also found that $^{13}C/^{12}C$ ratio in tissue increased as rainfall of the year when the tissue was formed decreased.

Finally, in a study conducted with Acer negundo, Dawson and Ehleringer (1993) found that males have lower conductance, transpiration, photosynthetic rate, C_i, and Δ and higher WUE than females. They concluded that these aspects may explain why under drought conditions the sex ratio (male/female) is male biased (1.62).

SUMMARY

From the literature reviewed, we can conclude that in general Δ is negatively correlated to WUE. Carbon isotope discrimination analysis is a useful technique in breeding programs for crops. This technique may be useful to identify variation in WUE of woody plants in order to select drought tolerant trees for agroforestry.

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AGROFORESTRY RESEARCH AT THE UNIVERSITY OF NEBRASKA[1]

James R. Brandle[2] and Tom D. Wardle[3]

The Department of Forestry, Fisheries and Wildlife and the Nebraska Forest Service are engaged in numerous agroforestry research and demonstration activities throughout the state. We have broken these down into two general areas, research projects and demonstration projects.

DEMONSTRATION PROJECTS

The Nebraska Forest Service is the state forestry agency and is part of the Department of Forestry, Fisheries and Wildlife. As such, foresters within the Nebraska Forest Service work closely with researchers in the Department. This provides unique opportunities for investigating field problems encountered by district staff in dealing with landowners. For example, a new study beginning this summer will address several questions concerning the effectiveness, efficiencies, and economics of fabric mulches on tree establishment.

In addition, a variety of plantings have been established, at different locations in the state, to provide full scale field demonstrations of selected agroforestry activities. Species trials, demonstration firewood production plantings, and seed production areas have all been established. A new area near North Platte, Nebraska, will contain several agroforestry demonstrations including a windbreak system on 110 acres of cropland.

In addition to these activities on public land, private cooperators have established a wide variety of practices and many of them invite others to visit their property. These visits offer excellent opportunities for interested individuals to see and learn first hand about the potential roles of agroforestry within their farming or ranching operations.

RESEARCH PROJECTS

The Department of Forestry, Fisheries and Wildlife conducts a wide variety of research in the general area of agroforestry. The largest project involves the influence of woody vegetation on sustainable agricultural systems. Under this project are many smaller projects, most

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[1]Paper presented at the U.S./Mexico Workshop on "Potentials for Agroforestry in Northern Mexico Workshop; Saltillo, Coahuila, Mexico; April 12-15, 1994.

[2]Associate Professor, Department of Forestry, Fisheries, and Wildlife, East Campus - UNL, Lincoln, NE, USA 68583-0814.

[3]Deputy State Forester and Associate Forester, Department of Forestry, Fisheries and Wildlife, East Campus - UNL, Lincoln, NE, USA 68583-0814.

involving graduate students in the Department.

The influence of shelter on grain crop production has been a subject of continuing research since the mid-sixties. Early work was conducted by Professor Walt Bagley (retired) and is currently being conducted by Dr. Jim Brandle. Over the years, studies on winter wheat, soybeans, and corn have indicated yield increases of 15% for wheat, 20-25% for soybeans and 12% for corn. In addition studies have been initiated to investigate the different mechanisms that result in these yield increases. In the case of wheat, yield increases can be attributed to the protection provide by shelter during the late winter and early spring. In the case of soybeans, the yield increase is related to canopy architecture. Current studies in cooperation with Dr. Michele Schoeneberger of the USDA Forest Service are directed toward determining the interactions between trees and crops in terms of competition for moisture and nutrients. These and related studies are part of a large integrated farm being developed near Mead, Nebraska, under the Center for Sustainable Agricultural Systems.

Investigations on the influence of shelter on vegetable and forage crops is just beginning. At present, in cooperation with Dr. Laurie Hodges of the Department of Horticulture and Dr. Ken Hubbard of the Department of Agricultural Meteorology, four studies are being conducted on the influence of microclimate on vegetable production. Crops include muskmelon, cabbage, snap beans and alfalfa. Again most are being conducted by graduate students. Preliminary results indicate an increase in early yield from sheltered plots due to an increase in air and soil temperatures early in the season.

The economic benefits of shelter are being assessed with a computer model designed to help landowners determine the economic returns from an investment in a field windbreak system. This work is being conducted by Dr. Jim Brandle and Dr. Bruce Johnson of the Department of Agricultural Economics and Mr. John Kort of the Shelterbelt Centre of the Prairie Farm Rehabilitation Administration, Agriculture Canada. The second generation model has recently been released and the third generation is under development. The model is adaptable to the international scene and a version has been developed for Pakistan.

The effect of shelterbelt structure on windflow and microclimate is a new study being conducted in cooperation with Dr. R.A. Schmidt of the USDA Forest Service, Dr. Irina Litvina of the Agrophysical Research Institute in St. Petersburg, Russia, and Dr. Gene Takle of Iowa State University. The project is designed to develop a model of shelterbelt efficiency and to develop a method of determining a quantitative measure of shelterbelt porosity. Currently, two graduate students are supported by the project, one at the University of Nebraska and one at Iowa State University.

The regional effects of shelterbelts and the impacts of potential climate change are being investigated in a cooperative effort with Drs. R.A. Schmidt and Michele Schoeneberger of the USDA Forest Service, Dr. Gene Takle of Iowa State University, Dr. Irina Litvina, Agrophysical

Research Institute, and Dr. Bill Easterling of the Department of Agricultural Meteorology. This project involves extending the impacts of individual field shelterbelt systems and other types of linear woody vegetation, ie. riparian areas, to a regional scale, determining the economic benefits at a regional scale, and assessing the impact of climate change on these regional effects. The project supports two graduate students, one at the University of Nebraska and one at Iowa State University and a postdoctoral fellow at Nebraska.

The impact of linear woody vegetation on the distribution of Insect pests and their natural enemies in sustainable agricultural systems is being determined in an interagency study with Dr. Mary Ellen Dix of the US Forest Service, Dr. Bob Wright of the Department of Entomology, Dr. Ken Hubbard of the Department of Agricultural Meteorology, Dr. Laurie Hodges of the Department of Horticulture, and Drs. Jim Brandle, Mark Harrell and Ron Johnson of the Department of Forestry, Fisheries and Wildlife. This project currently supports two graduate students. This area is of primary interest to the group working on agroforestry systems and will be the focus of additional research. Our short term goal is to better understand the relationship between woody vegetation and the distribution and population dynamics of crop pests, insect predators and birds. Intermediate term we want to understand the role that trees play in supporting populations of natural predators such as predatory insects (example lady bugs), birds, and small mammals (for example bats or mice). Our long term overall goal is to determine if there are differences in pesticide usage at the landscape scale in areas with linear woody vegetation when compared to treeless areas. Knowledge of the relationships between various types of vegetation and its arrangement on the landscape will allow us to provide guidelines on the potential benefits of manipulation of habitat to encourage natural predators and may lead to reductions in pesticide usage. An associated goal is conservation of biodiversity in agricultural landscapes, including conservation of neotropical migrant birds.

The impacts of wildlife populations in agricultural systems are under study by several faculty. Specific studies include: The effect of pocket gophers on two varieties of alfalfa with different rooting habits (Dr. Ron Case), deer damage and control in corn production (Dr. Scott Hygnstrom), the effects of conservation reserve lands on distribution of grassland birds (Dr. Julie Savidge), local and landscape factors affecting avian communities and overall biodiversity (Dr. Julie Savidge), and relationships between prairie dog towns and burrowing owl populations in rangelands (Dr Julie Savidge). All of these projects support graduate students.

The benefits of shelter on winter livestock grazing are being investigated in a joint study with Dr. Terry Klopfenstein of the Department of Animal Science. Funding was received through the Center for Sustainable Agricultural Systems and supports a graduate student in Animal Science. The project is part of a large integrated farm being developed under the Center for Sustainable Agricultural Systems which promises numerous opportunities in the future both in terms of research

and graduate education.

The influence of landscape structure on biodiversity and wildlife habitat use is the focus of work lead by Dr. Dennis E. Jelinski in collaboration with Drs. Brandle, Case and Hygnstrom as well as personnel from several resource managing agencies including the US Fish and Wildlife Service and The Nature Conservancy. This work examines how large-scale, synoptic conditions affect species abundance and distribution, how this varies with spatial heterogeneity in the landscape, how species move among remnants within the agricultural matrix, and what types of corridors are necessary to promote movement among populations; in other words, how ecosystems are functionally connected into a landscape. Dr. Jelinski is also establishing a project that examines the relationship between bird diversity and grassland patch size and agricultural activity in the surrounding area. Currently the project supports three graduate students with several new students scheduled to begin in September 1994.

The effects of woody riparian vegetation along streams and rivers in Nebraska is the subject of several investigations in the Department, in cooperation with the USDA Forest Service, as well as the Nebraska Department of Environmental Quality, the Lower Platte North NRD, and EPA Region VII. Riparian buffer strip composition, configuration and their placement in the water shed are areas currently under investigation, particularly with regard to their ability to improve water quality in agroecosystems. Both basic research and demonstration projects presently support at least four graduate students and foster collaborative efforts among several UNL faculty including Jim Brandle, Kyle Hoagland, Dennis Jelinski, and Michele Schoeneberger. Research to test for optimal riparian strip design, by establishing short- and long-term experimental riparian plots, is also being planned.

RIPARIAN BUFFER SYSTEMS TO PROTECT WATER QUALITY[1]

Michael Dosskey[2]

INTRODUCTION

The Center for Semiarid Agroforestry is currently expanding its research programs into riparian zone land use. Riparian zones generally refer to lands adjacent to streams, ponds, and lakes. In agriculture-dominated regions of the U.S. there is growing interest in the management of riparian zones for purposes other than crop production. One management alternative, the establishment or restoration of healthy riparian forests, may offer a solution to water quality problems which are endemic in agricultural regions. Our research program currently focuses on designing riparian buffer systems to protect water quality in the semiarid, central U.S.

ISSUE: WATER QUALITY IN THE U.S.

Clean, fresh water is one of our most vital natural resources. Every day we need vast quantities of clean water for domestic consumption, industry, and agricultural uses. Clean water also supports healthy and productive aquatic ecosystems and resources. Water to support these activities normally drains from healthy, naturally-functioning terrestrial ecosystems.

Our problem is that human uses of landscape and water resources are resulting in detrimentally high levels of pollutants in streams, lakes, and groundwater. The indicators are damaged aquatic habitats and resources. The impact for people is decreasing supply of clean water at a time of rapidly growing demand.

The U.S. Congress recognized this serious water quality problem by establishing the Federal Water Pollution Control Act of 1972 and subsequent amendments. This law demands reduction of pollutant levels in our water sources and imposes penalties on polluters for noncompliance.

Over the last 20 years, we have seen effective control of many industrial and domestic (point) sources of pollution. However, serious water quality problems persist.

IMPLICATIONS FOR U.S. AGRICULTURE

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[1]Paper presented at the U.S./Mexico Workshop on "Potentials for Agroforestry in Northern Mexico"; Saltillo, Coahuila, Mexico; April 12-15, 1994.

[2]Research Ecologist, USDA Forest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822.

Currently, pollution from nonpoint sources is the major water quality problem in the U.S., and comes dominantly from agricultural lands (Carey, 1991). Agricultural pollutants include sediment, fertilizers, pesticides, and livestock wastes which enter our water supply as components of rainfall runoff. This problem is particularly acute in the central U.S. where there is a very high proportion of land used for agriculture.

Several factors contribute to the persistence of this problem. Chief among them are: (1) commodity-driven land-use philosophy, and (2) high-yield agricultural systems. Economic pressures on farmers encourage bringing maximum acreage into production, including streamside and highly-erodible lands. Our high-yield agricultural system, which is unparalleled in its ability to produce food and fiber, requires high inputs of fertilizers, pesticides, in combination with soil tillage. Within this system, streams are commonly regarded as drainageways to assist agricultural production.

In order to comply with U.S. law, farmers must reduce agricultural pollution. But, the economic well-being of farmers and agricultural communities must also be protected by developing pollution control methods which do not sacrifice production and farm income.

ROLE FOR FORESTED RIPARIAN BUFFERS

Recent research has shown that riparian (streamside) forest can improve the quality of water by withholding and removing agricultural pollutants from runoff (Welch, 1991). As protected strips (buffers) along streams, riparian forests remove streamside areas from tillage and agri-chemical application, and stabilize the soil. Riparian vegetation also acts as a "filter" to remove pollutants from field and feedlot runoff before the water enters streams.

The "filtration" properties of forested riparian buffers may be particularly useful for reducing agricultural pollution. Within a riparian buffer, pollutant-laden runoff water slows and diffuses across the ground surface. Sediment and sediment-bound pollutants settle among, or are trapped by, surface litter. Infiltration into the soil immobilizes soluble pollutants. Once in the soil, plants absorb nutrient pollutants, and microbial processes degrade and transform nutrients, pesticides, and animal wastes into innocuous forms (Welsch 1991).

Forested riparian buffers have been shown to remove 40 to 90% of nutrient N and P from runoff water (Lowrance et al. 1984; Peterjohn and Correll 1984). For other pollutants, only grass buffers have been tested thus far, and these results show 12-75% removal of sediment, pesticides, and coliform bacteria (Arora et al. 1993; Mickelson and Baker 1993; Young et al. 1980). High rates of removal make forested riparian buffers a very promising pollution control practice.

Forested buffers can also provide many other important benefits. Trees are able to shade adjacent streams and help maintain cooler water

temperatures necessary for healthy aquatic animals. These forests also become ideal wildlife habitat, and if managed properly, can be a source of marketable products (e.g., lumber, fuelwood, nuts, fruit, hay). Most importantly, these benefits are sustainable.

Based on our current knowledge, multistrata (grass/shrub/tree) forest buffers may be the best species composition for providing water quality and other benefits (Welsch, 1991). The grass component establishes quickly and is best to slow incoming runoff and trap sediments. Trees and shrubs take longer to establish than grass, but have deeper and more extensive root systems. These woody plants may be more effective in promoting infiltration, plant uptake, and degradation processes, even in shallow groundwater. Trees also provide superior shade and bank stabilization. Our current hypothesis is that a combination of grass, shrubs, and trees provides the best overall, long-term, water improvement, optimum wood and wildlife benefits, and is easiest to maintain. However, the actual role of trees and other woody plants in improving water quality remains to be confirmed.

CSA RIPARIAN RESEARCH PROGRAM

Our current riparian research activity involves evaluating buffer systems for improving water quality in the semiarid central U.S. This program is being developed, and is growing rapidly.

Basic research activity is directed at exploring how riparian buffer processes remove pollutants from agricultural runoff, particularly the role of trees. In the course of these studies, we will determine how well buffers work in the central U.S. region and ways to make them more effective.

Our applied research is aimed at using results of basic research to develop guidelines for establishment and management of riparian buffers. Some important factors we are addressing are: land preparation requirements, best species composition, minimum effective width, location for maximum runoff interception, whether to utilize or replace existing vegetation, management required for maintaining maximum performance, among others.

Our immediate goal is to utilize the natural processes in riparian forests to provide a cost-effective means for farmers to reduce agricultural nonpoint-source pollution. The advantage of using riparian vegetation to improve water quality, as opposed to reducing in-field fertilizer and pesticide use, is that it potentially can have little negative impact on commodity production.

The future direction of this program is toward developing more integrated buffer systems. Buffer systems will be combined with constructed wetlands and channel- stabilizing plantings for optimum water quality control. Ultimately, our goal is to develop buffer designs which optimize many desired benefits (e.g., water quality, wood products, wildlife habitat, aesthetics), and which blend well with in-

field agricultural practices. Eventually, riparian buffers will become an integral part of sustainable agricultural systems which provide for optimum economic and social wellbeing of agricultural communities.

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PRODUCTION AGROFORESTRY IN THE UNITED STATES[1]

W.J. Rietveld and Peter F. Ffolliott[2]

ABSTRACT

Tree products to enhance farm income are the primary goals of production agroforestry. Trees integrated into agricultural production systems help to utilize all of the farm and increase the overall productive capacity of the land. Establishing a production agroforestry system can result from converting unsuitable farmland to a tree crop or from integrating trees into the farming system. Practices can be grouped into block plantings and row plantings. Block plantings include high-value hardwood plantations, fuelwood plantations, woodlots, Christmas tree plantations, tree/pasture systems, and wildlife habitat. Row plantings include alley cropping, windbreaks and hedgerows, boundary plantings, home gardens, and riparian areas. Products directly from the trees include sawlogs and veneer, fuelwood, Christmas trees, posts, fruits, nuts, pine straw, cones, seeds, foliage, and fodder. Production agroforestry also includes tree production systems that enable growing a sensitive crop (fruits, vegetables, herbs). Besides tree products for profit, production agroforestry practices simultaneously provide a broad array of conservation and environmental services. Few farm practices can match the capacity of agroforestry to enhance the economic, environmental, and social elements of the system.

INTRODUCTION

Production agroforestry is tree planting in agriculture-dominated environments to provide tree products and income as the primary objectives. Trees integrated into agricultural production systems help to utilize all of the farm and increase the overall productive capacity of the land. Production agroforestry practices can be either block plantings or row plantings that are integrated into agricultural production systems. It may also include agroforestry practices that provide protection for sensitive crops (fruits, vegetables, herbs) enabling their production in an environment otherwise too hostile.

Production agroforestry should be distinguished from conservation agroforestry in which trees and shrubs are planted primarily for the conservation and environmental services they provide to the system.

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[1]Paper presented at the U.S./Mexico Workshop on "Potentials for Agroforestry in Northern Mexico"; Saltillo, Coahuila, Mexico; April 12-15, 1994.

[2]W.J. Rietveld is Program Manager, USDA Forest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822; Peter F. Ffolliott is Professor, University of Arizona, School of Renewable Natural Resources, 325 Biological Sciences Building, Tucson, AZ, USA 85721.

Conservation agroforestry is tree and shrub planting in agriculture-dominated environments wherein trees and shrubs conserve soil and water; protect crops, Livestock, farmsteads, roads, and Wildlife; enhance environments for people; Diversify species and landscapes; sustain productivity, natural resources, and people; and provide recreation and amenity benefits. Production agroforestry and conservation agroforestry are not mutually exclusive; their goals are met simultaneously in many instances.

WHY PRODUCTION AGROFORESTRY?

Production agroforestry can provide additional farm products and sources of income over a range of farm sizes, ownerships, climate zones, and cropping systems. The reasons for incorporating production agroforestry practices into a farming system are diverse and listed here with brief descriptions.

Increase Overall Productive Capacity. Integrating a tree crop with annual crops allows growing multiple crops simultaneously and utilizing all of the farm, increasing the overall productive capacity from an often limited land base. When trees are intercropped with other crops, each crop utilizes a different above- and below-ground stratum, has different growth requirements and different phenology. Also, planting a tree crop on parts of the farm not accessible or suitable for annual crops provides a means to effectively use all of the farm.

Provide Additional Sources of Income. Tree products, such as logs, posts, or Christmas trees, can be sold to provide additional farm income. Also, growing needed materials on-farm, instead of purchasing them, allows farm revenues to be spent for other purposes, effectively creating additional income for farmers.

Supply On-Farm and Local Needs. Agroforestry provides a means to be more self-sufficient. Tree products, such as posts, timbers, lumber, and fuelwood can be consumed on the farm, traded, or sold to obtain needed materials or cash.

Diversify Local Economies. Diversification can reduce the risks in local economies limited by markets for products from single-cropping practices. When established at an appropriate scale, production agroforestry systems and the markets they develop can have a significant effect on the local economy.

Provide Environmental Services. Agroforestry is one of the few farm practices that can simultaneously enhance the economic, environmental, and social elements of the system.

Attain More Sustainable Systems. Trees and their associated organisms enhance biodiversity, protect soil, water, and crops, and increase system resiliency to climatic extremes. Enhancing species diversity may not necessarily achieve sustainability, but the diversity introduced from agroforestry distinguishes it from "monocultural" systems that are

less sustainable in general.

POTENTIAL LOCATIONS FOR PRODUCTION AGROFORESTRY

Approximately 159 million acres of economically-marginal or environmentally sensitive croplands are potentially available for conversion to production agroforestry in the United States. This includes lands that are severely eroded, highly erodible, nutrient-depleted, subject to frequent flooding, and fields that are too small or steep to operate conventional farming equipment. These lands are in need of permanent vegetative cover, rather than tillage and cropping. Since most farmers want to grow a crop on as much of their land as possible, a tree crop may be the most suitable and productive for these lands.

Additionally, agroforestry practices can readily be integrated into a production agriculture system by utilizing available nitches within the system. These include row and block plantings within existing field, boundaries, corners, and riparian zones. These nitches represent unused space on many farms, as far as annual crop production is concerned, and could be utilized for a tree crop.

PRACTICES

Production agroforestry practices can be grouped into block plantings and row plantings. In a block planting, a block of land ill-suited to other farming purposes is converted to a tree crop. In a row planting, trees are added to an annual crop or pasture to establish a multi-crop system.

Block Plantings

High-Value Hardwood Plantations. High-value hardwoods, such as walnut, ash, and oak, have the potential to provide valuable sawlogs and veneer. Walnut requires deep, rich, well-drained soils and adequate soil moisture. Therefore, the opportunities are limited in the semiarid zone, except for flood plains and irrigated farmlands. Plantations are often established on bottomland fields that frequently flood, destroying conventional crops. Oak, honeylocust, and other more adaptable hardwood trees can be grown in "silvopastoral" (tree/pasture) systems to provide both a tree and a forage crop.

Fuelwood Plantations. Fuelwood is a good alternative tree crop for conversion of marginal farmlands. Species that readily coppice, such as poplar, maple, and sycamore are well suited for fuelwood plantations. The planting density depends on the species and available soil moisture. Fuelwood can be a valuable product, especially in locations where a strong demand exists because of scarcity, or a major market exists such as a nearby power plant or city.

Woodlots. Many farmers like to have a small fuelwood plantation or

woodlot to supply their on-farm needs. Non-arable parts of farms are often used as woodlots. Farmers can often receive good income from selling timber from their woodlots. Fuelwood is also readily available as a secondary product.

Christmas Tree Plantations. Christmas trees can provide a high return on otherwise marginal agricultural land, but only if an accessible market exists. Before growing a crop of Christmas trees, a farmer must First check on the market opportunities. Also, farmers need to be prepared for the labor and time required for annual pruning and maintenance Christmas trees.

Trees/Pasture Systems. Also known as "silvopastoral" systems, growing scattered trees in pastures provides tree products and increases forage and livestock production. The partial shade from the trees increases forage production, and the trees themselves will eventually provide a timber product. Oak, honeylocust, and other more adaptable hardwood trees can readily be grown in Silvopastoral systems to provide both a tree and a forage crop.

Wildlife Habitat. Although this is more of a conservation agroforestry practice, income can be derived from judicious harvesting of timber, feehunting, and non-consumptive use of wildlife.

Row Plantings

Alley Cropping. Alley cropping is an agroforestry concept that uses strips of trees or shrubs with crops grown in the alleys between the strips. The trees may include valuable hardwood species or nut trees. Agricultural crops grown between the tree rows provide short-term return from the land during the early years when the longer-term nut or wood crop is establishing itself.

Windbreaks and Hedgerows. These plantings can provide timber and fuelwood when they need to be thinned. Also, nut trees can be grown in windbreaks and hedgerows, and live fences allowing the trees to serve a multiple purposes.

Boundary Plantings. Property and field boundaries provide an opportunity to grow a tree crop. Pines, or other narrow species are often used for this purpose. If the lower branches are pruned, they can provide valuable poles or sawlogs when mature.

Home Gardens. This traditional land-use practice consists of growing trees and vegetables together in a garden close to the home. Multi-story designs more fully utilize vertical space above- and below-ground. The trees typically provide fruit, nuts, fodder, poles, and fuelwood. Tree species are carefully selected to minimize competition with vegetable crops.

Riparian Areas. Riparian zones are linear forests or woodlots. Because Riparian zones usually have fertile, moist soils they have excellent

potential to grow trees for timber and a variety of other tree products.

PRODUCTS FROM PRODUCTION AGROFORESTRY

Agroforestry yields direct products and indirect benefits from the trees. We prefer to call them "tree products" because the array of income-producing products goes far beyond sawlogs, especially in arduous climates where tree protection enables growing of sensitive crops.

Products Yielded directly from the trees include sawlogs and veneer, fuelwood, Christmas trees, posts, fruits, nuts, cones, seeds, foliage, and fodder. Products yielded indirectly from the trees include vegetables, grains, fruits, nuts, honey, forage, hay, hunting, recreation, livestock, and herbs.

The importance and value of these products depend on the situation and scale of the operation. On subsistence farms, trees can provide basic structural materials, food, or fodder so that these items do not need to be purchased. Beyond on-farm needs, opportunities exist at various operational scales to sell tree products for additional farm income. On commercial farms, production agroforestry systems can be an excellent way to profitably utilize portions of the farm that might otherwise be non-productive.

NON-PRODUCT BENEFITS FROM PRODUCTION AGROFORESTRY

Although the primary objective of production agroforesty is tree products for profit, these practices simultaneously provide numerous conservation benefits. These non-product benefits are identical to those from conservation agroforestry. They include enriching the soil and holding it in place, sequestering and degrading excess nutrients and pesticides, improving Microclimates, reducing runoff and flooding, increasing wildlife populations, reducing energy costs, improving aesthetics and property values, and improving landscape and biodiversity. The multiple economic and conservation benefits from agroforestry land-use systems that are productive, stable, diverse, and aesthetic.

CONCLUSION

Few farm practices can match the capacity of agroforestry to simultaneously enhance the economic, environmental, and social elements of the ecosystem. In addition to resource protection, agroforestry systems offer new opportunities for rural development and rural economic diversification. In various types of agroforestry systems, numerous products can be provided either directly from the trees or as a result of the protection provided by the trees. The location of agroforestry plantings and the types of products provided need to be carefully planned to meet landowner objectives. This can range from subsistence

farms, where growing needed structural materials, food, and fodder can reduce the need to purchase them, to commercial farms where tree products can be grown for profit at different scales. Agroforestry provides a means to utilize all of the farm, and at the same time establish a more sustainable farming operation that will be resilient to losses from climatic extremes.

RESOURCE ANALYSIS RESEARCH TO COMPARE THE ECONOMIC, ENVIRONMENTAL, AND SOCIAL BENEFITS OF AGROFORESTRY OPTIONS[1]

Lita C. Rule,[2] Joe P. Colletti,[3] Richard R. Faltonson,[4]
Jim Rosacker,[5] and Darrell Ausborn[6]

INTRODUCTION

Agroforestry is a land use option that has been increasingly identified as environmentally sound and hailed as a sustainable system. The sustainability of agricultural land use practices, agroforestry included, is determined by several factors. York (1988) classified these factors into three groups: biological, physical, and socioeconomic and legal. The interaction of these three groups of factors often constitute the basis of all production systems. The desirability of a land use system may be evaluated using a simple maxim often associated with acceptance of innovations: the system must be biologically and technically feasible, economically viable, socially acceptable, and politically responsible. However close to the old ways the new practices are, decision making concerning land use changes is not easy. Wood (1988) says that this decision making process "requires study of the problems to be solved and the potentials to be realized, together with knowledge of the range of possible alternatives." Thus, if agroforestry systems are to be planned for or introduced into a certain location, the farmers or those involved with the practice should first be able to identify their own economic goals and social interests, and understand the limitations of the natural and physical resources.

It is only logical then that the diagnostics start with what the people know, what they have, and where they want to go from where they presently are. The following study illustrates the identification of various options and the goals that are addressed by each option, as the landowners involved (a Native American tribe) explored other possible

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[1]Paper presented at the U.S./Mexico Workshop on "Potentials for Agroforestry in Northern Mexico"; Saltillo, Coahuila, Mexico; April 12-15, 1994.

[2]Assistant Professor, Department of Forestry, Iowa State University, Ames, IA, USA 50011-1021.

[3]Associate Professor, Department of Forestry, Iowa State University, Ames, IA, USA 50011-1021.

[4]Research Coordinator, Department of Forestry, Iowa State University, Ames, IA, USA 50011-1021.

[5]Coordinator for Winnebago Tribe Project, Department of Forestry, Iowa State University, Ames, IA, USA 50011-1021.

[6]Forest Manager, Bureau of Indian Affairs, Winnebago Agency, Winnebago, NE, USA 68071.

alternative land uses, including agroforestry, for a tract of tribal land.

THE WINNEBAGO TRIBE OF NEBRASKA

A study of various forestry and agricultural alternatives for a 1255-acre tract of land owned by the Winnebago Tribe of Nebraska was done in 1991 by an interdisciplinary team of forest biologists, rural sociologists, forest soil scientists, and forest economists from Iowa State University. The study was guided by general land use and site specific objectives expressed by the Tribe. The Tribe wanted an evaluation of converting the land from the present intensive row crop production into other uses, including forestry and agriculture and a mix of both (or agroforestry), within a 10-year period. The area, Big Bear Hollow (BBH), has been in corn and soybean production for over 20 years. A non-Native American farmer currently rents the land on a five-year lease. Located on the Missouri River floodplain about seven miles east of Winnebago, Nebraska, the area is bounded by the Missouri River to the east and by forested bluffs to the west. An important Tribal recreational area, Glover's Bend also lies to the east. The very nature of the objectives the Tribe has expressed for their land and the framework within which these objectives were addressed are features of this research.

OBJECTIVES

The study involved an evaluation of alternative land uses for BHH Tribal land under intensive agricultural production. It was intended to assist the Tribe in fulfilling the resource management goals expressed in their 1989 Land Use Plan that was prepared for the Tribe by the Johnson-Trussell Company. The general goal of the Tribe was "to develop a long-term land use management plan for BBH to attain economic, environmental, and social objectives through the promotion of tribal values" (Johnson-Trussell Co., 1989).

The objectives of this study were: (1) to identify the objectives of the Tribe for BBH, (2) to establish the decision criteria to evaluate the objectives, (3) to assess the capabilities of the Tribe's human and natural resources as related to BBH, (4) to develop alternatives for possible conversion of BBH into forest crops or a combination of forest and agricultural crops, and (5) to evaluate each alternative in terms of the economic, environmental, social, and institutional/political effects.

PROCEDURE

The study had three phases. The initial phase was the scoping process to identify all Tribal objectives relating to BBH, to identify the decision criteria to evaluate objectives, and to establish baseline resource capabilities for human/cultural and natural resources. The second was the development of a set of alternatives that address the various objectives declared by the Tribe for BBH. An alternative consisted of

one or more types of land uses called management regimes.

The third phase was the determination of effects for each alternative and their comparison considering various weighting of economic, social, environmental, and institutional/political criteria. Interviews with the Tribal Council, Tribal elders, and other community members provided a set of objectives for BBH. Scoping activities also developed data on resource capabilities and other relevant information regarding Tribal land use, and produced a set of criteria to be used to evaluate the specified Tribal objectives. For instance, to measure the goal of enhancing soil fertility, criteria dealing with soil erosion and bulk density and nitrate nitrogen were used. Most criteria were developed using site-specific data collected about biophysical factors. Thus, "well yield" was measured in terms of acre-feet of water. Other criteria were indices, such as the "soil erosion" index. These indices were especially helpful where information was incomplete or not available. For some goals, for which no apparent measurement existed, such as the transfer of knowledge from one generation to another, the decision criteria were developed by consensus of the researchers through group interaction. More discussion of these criteria is given towards the end of this section. A more detailed description of criteria development is given in the Winnebago Forest and Agriculture Alternatives Feasibility Study Final Report [1992].

The nominal group process (NGP) was used to develop and rank the objectives that were identified for BBH. The NGP is a consensus-building procedure about critical information needs that involves a series of steps. First, each individual group member develops a list of items in response to a specific question posed before the group. These individual responses are then collected and listed by a facilitator. A brief discussion follows to clarify what each item means. Independent ranking by each member is then held, followed by the development of group rating for each item by combining the individual ratings [Schomaker and Lime, 1988]. The nominal group technique is often used in identifying critical issues or in assessing needs, and then developing the appropriate information into a package or form that researchers or managers can use. The process has been used successfully in various fields, including planning, policy making, management, education, and other sciences or fields of research, both in the private and public sectors [Langone, 1990; Schomaker and Lime, 1988; Pokorny et.al., 1988; Mahler, 1987].

In this study, the NGP involved a group of Tribal Council members and Tribal elders. The NCP started with a set of 20 objectives previously identified for BBH area from tribal documents and earlier interviews. During the meeting, the items were briefly discussed and another objective was added. Then the new set of 21 objectives was evaluated by each group member. Each member was instructed to assign a value from 0 to 10, with 10 being the highest score, to each objective. Then for each objective, all values were summed to yield a group ranking. The results were then presented to the group for discussion. This was followed by individual re-evaluation of his/her own original valuation, with the instruction that they can modify their evaluation if they so wished. The

final step produced a second and final overall group ranking, which represented a consensus valuing of each objective by the Tribe.

The development of alternatives considered the Tribal objectives from the NGP, cultural and natural resources, and several additional land use guidelines from the Tribal Council and the Bureau of Indian Affairs. These guidelines included: 10-year phased-in implementation schedule, development of a black walnut plantation, consideration of foregone cash rent from the current land use of BBH, establishment of a 55-acre shelterbelt planting along the Missouri River in 1991, a short-rotation woody crop plantation, agroforestry systems, Impacts of the Food and Agriculture Conservation and Trade Act (1990), state-level policies on agronomic/forestry/agro-forestry crops, and the impact of the Army Corps of Engineers' Missouri River management plan including the Glover's Bend recreational area.

The analysis of alternatives involved determination of magnitudes associated with the decision criteria. The comparison of all alternatives considered the simultaneous impacts of the criteria on an alternative. A criterion measured the effect associated with an alternative for a 50-year period, and its impact could be easily compared across alternatives. But because the effects were measured in terms of dollars, number of people employed, tons of soil loss, wildlife habitat value, and so on, it was very difficult to sum all of the magnitudes within an alternative, and to compare the alternatives. To solve this comparability problem, the magnitudes for all criteria across all alternatives were scaled using the 2 statistic [Canham, 1990], which allowed for all magnitudes for any given alternative to be summed up in order to yield an overall score for that alternative. The Z-statistic is defined as:

$Z_j = F(x_{ij} - x_m, S_x)$ for j=1 to n, the total number of decision criteria where x_{ij} = the raw magnitude or response value (a data value) for alternative i (i=1 to k) the total number of alternatives

x_m, = mean of all magnitudes for a given criterion

S_x = standard deviation of all magnitude values

Z_j = a standardized score for the jth decision criteria

Thus, the Z-score shows the relative relationship of the individual magnitude to the mean or average; it indicates how far the magnitude is from the mean relative to the standard deviation.

To highlight the different socioeconomic and environmental perspectives that could be taken to evaluate the alternatives, four weighting schemes were used to compare the alternatives. These schemes were based on : (1) actual criteria weight values as determined by the Nominal Group process, (2) equal weight for each criterion, (3) high weight given to environmental criteria, and (4) high weight given to economic criteria. For each weighting scheme and each alternative, the Z-scores are multiplied by the weights assigned to the criteria. For example, in

giving priority to economic criteria, it was assumed that all economic criteria were ten times as important as all other criteria. Hence, the 2-scores for the economic criteria were multiplied by a weight of 10.0 and for all other criteria their 2-scores for all alternatives were multiplied by 1.0. Also, several criteria were established to measure the attainment of the objectives identified by the Tribe as important to them. In most cases, only one criterion was identified for one objective. However, in cases where two criteria were used to measure one objective, each criterion was given one-half value toward the attainment of that objective. The weighted Z-scores could be summed for an alternative and the total weighted score for each alternative could be directly compared then. The alternative with the greatest total weighted score would be the "best" for that weighting scheme.

The economic criteria were Present Net Worth (PNW), annual cash flow, and employment. These criteria emphasized activities that provide net returns to people such as jobs and farming income. Based on the components included in each alternative, opportunities for seasonal and full-time employment were identified and cashflows for cropping systems involved were determined.

The environmental criteria measured outputs and impacts for soil, water, habitat, and other environmental indicators. These criteria included well yield, water use for irrigation, crop water use, soil loss, organic matter, bulk density, nitrogen fertilizer, pesticide danger, species diversity, and game and wildlife habitat. Well yield was based on the actual amount of groundwater used for irrigation in each alternative. Water from the Missouri River was based on the amount of water pumped directly from the Missouri River for irrigation. The Blaney-Criddle method [Finkel 1982] was used to estimate crop water use for various land uses based on precipitation and evapotranspiration. Soil loss, organic matter, and bulk density criteria used estimates of inputs of organic matter and levels of soil disturbance to assign relative indices of soil quality to various land uses. The nitrogen fertilizer criterion was based on actual amount used, while pesticide danger was an index developed using information on types of pesticides used, leaching and surface loss potentials of those pesticides and their persistency and toxicity. Species richness measured the number of representative species of plants and animals found in each alternative. Wildlife habitat used the Habitat Evaluation Procedure [U.S. Fish and Wildlife Service 1980] to determine the habitat suitability of each alternative for four representative game animals (white-tailed deer, fox squirrel, eastern wild turkey, and eastern cottontail rabbit).

The social criteria dealt with responses on educational and recreation concerns and internal cultural interactions. They included educational and recreational opportunities, hunting activities, Tribal control of land use, enhancement of intergenerational interaction among members, and complementarity of alternatives with surrounding developments. These were mostly indices that were developed based on the opportunities provided by the various components of each alternative. For instance, alternatives with more predominantly forestry components could offer

more educational, recreational, and intergenerational interaction opportunities and greater tribal control of land use as compared to the status quo or alternatives with primarily agricultural leanings.

The institutional/political criteria measured the opportunities for outside funding and technical support for the alternatives. These criteria included enhancement of indian water rights claims, matching the Tribe's Land Use Plan with the alternatives, possible funding opportunities from the Bureau of Indian Affairs and other sources, and building continuity for the project. Based on their components, indices were developed to reflect relative rankings of alternatives with respect to each criterion. One criterion, the enhancement of the Tribe's water rights claims, was dropped because it was a legal issue beyond the scope of this research activity. However, relevant information on how the Tribe could possibly facilitate this objective was presented to the Tribe.

RESULTS AND DISCUSSIONS

The scoping assessment activities produced a set of twenty-one objectives (Table 1) that were grouped into four categories: economic, social, environmental, and institutional/political. It is interesting to note that the NGP did not result in highly polarized opinions regarding importance levels of the objectives. In the final round, the NGP ranking produced a range from a low of 40 to a high of 87. Health risks associated with intensive agriculture and building continuity (project longevity) were identified as highest priority objectives. Also high on the list were the attainment of the Tribe's land use plan goals, its water rights claims, fostering of Tribal land use philosophy, and several environmental objectives such as enhancement of water quality and quantity, species diversity, wildlife habitat, and reduction of soil loss. The lowest ranked objective was the development of recreational opportunities for the Tribe.

Seven alternatives were developed, representing feasible alternative uses of BBH (Table 2). Alternative 1, the current situation (status quo), involved 1200 acres in irrigated and dry land corn and soybean production, and a 55 acres of shelterbelt along the eastern boundary on the Missouri River edge. Alternative 2 varied from the status quo by converting a quarter of the area in dry land crop production to black walnut, cottonwood, and other native bottomland forest species, such as green ash and silver maple. Alternative 3 retained half the area in irrigated agronomic production, and converted 20% to mixed, native bottomland forest and 30% to short-rotation woody crop production. Alternative 4 retained the central irrigation unit for alfalfa production on 25% of the area, and converted about 500 acres to forests, over 300 acres to short-rotation wood crops, and smaller portions of 40, 2, and 5 acres for indian corn, berries, and a wholesale container nursery operation, respectively. Alternative 5 removed the irrigation unit and alfalfa area, retained the berry patch/Indian corn/nursery operation areas, and put 96% of the land to forest to produce timber, wildlife, and recreational opportunities. Alternative 6 involved a 40-

acre demonstration/research plot in cooperation with the USDA Forest Service Center for Semiarid Agroforestry (located in Lincoln, Nebraska), and converted the rest to native forest. Alternative 7 represented complete conversion of the 1200 acres of agricultural land back to native bottomland forests. Table 2 shows the seven alternatives with the estimated acreages of the various components.

Table 1. Nominal group rankings for the Tribal objectives associated with alternative uses of Big Bear Hollow.

Objectives	1st Group Ranking	Final Group Ranking
1. To minimize health risks associated with farm chemical use	75	87
2. To build continuity	87	87
3. To enhance the water rights of the Winnebago Tribe of Nebraska	69	79
4. To enhance the water rights of the Winnebago Land Use Plan	66	78
5. To enhance quality & quantity of the water coming from the area	64	76
6. To enhance wildlife habitat	63	75
7. To enhance diversity of plants/animals of bottomland ecosystem	62	75
8. To enhance the complementary nature of the project with Glover's Bend (adjacentforested land on Missouri River)	64	75
9. To foster the Tribal philosophy of land use	61	72
10. To reduce soil loss	57	71
11. To enhance soil fertility	57	70
12. To foster long-term support of Tribal goals & objectives by the BIA	59	69
13. To minimize loss of income from converting site to other land uses	58	68

14. To maintain about the same cash flow as from leasing BBH	75	68
15. To foster hunting and fishing opportunities for the Tribe	58	66
16. To enhance the transfer of Intergenerational Tribal knowledge	57	66
17. To promote long-term opportunities for adult employment	54	61
18. To foster educational opportunities for the entire Tribal community	50	60
19. To promote opportunities for seasonal youth employment	46	58
20. To foster long-term support of Tribal goals and objectives by the Army Corps of Engineers	55	47
21. To develop recreational opportunities for Tribal members	43	40

Of the above alternatives, 2 and 3 represented predominant agricultural activities and some forestry, 4 and 5 were more diversified pursuits, while numbers 6 and 7 provided predominantly non-market (recreational and wildlife) outputs with other market goods. A complete description of the components of each alternative can be found in the Winnebago Forest and Agriculture Alternatives Feasibility Study Final Report [1992].

The raw effects or impacts were determined based on possible resource outputs, responses, and other criteria values or contributions for each alternative in the attainment of specific objectives. The data used came from the Bureau of 76 Indian Affairs, Soil Conservation Service, Nebraska USDA Forest Service, US Army Corps of Engineers were used. Although alternatives could be compared using raw impact data for one criterion at a time, e. g. , annual cash flow is highest for Alternatives 4 and 5, a more meaningful comparison could be made by considering all criteria for each alternative. To do this, the raw effects were scaled using the Z statistic to allow for all magnitudes for any given alternative to be summed, yielding an overall score for that alternative, as mentioned earlier. Alternatives could then be compared.

Table 2. The seven proposed alternatives and the estimated acreages of each component use.

MANAGEMENT REGIMES	ALTERNATIVES						
	1	2	3	4	5	6	7
Shelterbelts	55	55	55	55	55	55	55
Irrigated corn & soybeans	1040	900	600	0	0	0	0
Dryland corn & soybeans	160	0	0	0	0	0	0
Managed mixed bottomland	0	226	191	325	773	764	0
Managed cottonwood	0	36	20	0	60	46	0
Managed mixed walnut	0	38	4	0	39	67	0
Short rotation woody crops	0	0	385	338	0	0	0
Unmgd. mixed bottomland	0	0	0	171	194	190	965
Unmanaged cottonwood	0	0	0	15	65	65	125
Unmanaged mixed walnut	0	0	0	4	22	28	110
Irrigated alfalfa	0	0	0	300	0	0	0
Agroforestry demonstr. plot	0	0	0	0	0	40	0
Berry patch	0	0	0	2	2	0	0
Indian corn	0	0	0	40	40	0	0
Nursery	0	0	0	5	5	0	0

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Intensive Agriculture	Diversified Agroforestry	Complete conversion to forest
(irrigated corn/bean (dryland corn/bean)		(native bottom-land forest)

The comparative analysis among alternatives was carried further by applying the four different weighting schemes as described earlier. In each scheme, the Z-scores were multiplied by a specific weight assigned to the various criteria. Table 3 presents the weighted scores for each alternative for each

scheme. The negative values for the first three alternatives in all weighting schemes reflected the fact that these three alternatives had predominantly agricultural activities and had low forestry and other environmentally enhancing opportunities. Hence, one could expect low nominal, equal, and environmental scores for these options because the Tribe had already established preference for environmental and socio-political objectives through the NGP. These three alternatives were also low in economic weighting because full time or seasonal employment opportunities were zero or minimum in these alternatives, even with corn/soybean production going on. Alternatives 6 and 7 were low in economics as well because there was little or no cash income and only few employment opportunities at all.

Table 3. Sum of weighted scores for the seven alternatives, using four weighting schemes.

WEIGHTING SCHEMES	SUM OF WEIGHTED SCORES						
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Nominal Group	-965.06	-757.89	-383.42	638.31	735.31	357.69	379.31
Equal Weight	-15.37	-11.42	-6.05	10.25	11.53	5.28	5.36
Environmental Priority	-58.43	-54.95	-35.38	9.52	46.08	40.87	47.87
Economic Priority	-4.48	-9.67	-9.13	30.14	28.99	-17.67	-18.67

Table 4 summarizes the rankings of the seven alternatives using the four different weighting schemes. Using the Nominal Group scores, Alternative 5 was ranked first and Alternative 4 was second. Using Equal Weights, the rankings were similar to those derived by using the Nominal Group scores. This could be because the same preferential ranking by the tribe may have not been affected at all, although magnitudes may have changed proportionately. Giving high weight to the environmental criteria, Alternative 7 was first, followed by Alternatives 5, 6, 4, 3, 2, and 1 in decreasing order. Finally, when high priority was given to economic criteria, Alternative 4 ranked first and Alternatives 5 was a close second. This could be expected in the sense that Alternative 4 offered more cashflow opportunities than Alternative 5.

Table 4. Ranking of the seven alternatives using four weighting schemes.

WEIGHTING SCHEMES	RANKING						
	1st	2nd	3rd	4th	5th	6th	7th
Nominal Group	Alt. 5	Alt. 4	Alt. 7	Alt. 6	Alt. 3	Alt. 2	Alt. 1
Equal Weight	Alt. 5	Alt. 4	Alt. 7	Alt. 6	Alt. 3	Alt. 2	Alt. 1
Environmental Weight	Alt. 7	Alt. 5	Alt. 6	Alt. 4	Alt. 3	Alt. 2	Alt. 1
Economic Weight	Alt. 4	Alt. 5	Alt. 1	Alt. 3	Alt. 2	Alt. 6	Alt. 7

From the four weighting schemes, Alternative 5 seemed to be the best option, closely followed by Alternative 4. Alternative 5 included a berry patch, an Indian corn patch, a nursery operation area, and the rest (96%) of the area given to bottomland forest to produce timber, wildlife, and recreational opportunities. Alternative 4 had these same things, except that it had a smaller forested area, a short-rotation woody crop (biomass for energy) production area, and alfalfa production in one-fourth of the area.

Risk and uncertainty associated with components of the alternatives were considered but no formal risk assessment was done. A conservative approach was taken to determining outputs and prices for commodities with underdeveloped markets. Although some forestry and agricultural outputs such as nuts and berries are for Winnebago household consumption, pricing was based on regional markets. Risk was incorporated to an extent in the present net worth calculations via the real discounting factor. For example, the nursery operation was considered a high risk proposition in that it required a high level of technical and managerial skills, high capital cost of establishment, and uncertainty associated with markets for the nursery products. The short-rotation woody crops, although possibly profitable as suggested by research, are risky in that markets do not exist close to Winnebago, Nebraska. Both alternatives, however, were diverse mixtures of forestry and agricultural (agroforestry) operations, and both addressed most of the objectives.

CONCLUSIONS

The development of alternative land uses for Big Bear Hollow has been guided by a complex set of twenty-one land use objectives articulated by the Winnebago Tribal members and obtained by an interactive group process. The Tribal council, elders, and other members participated in the weighting of the twenty-one objectives. Seven alternatives were developed representing a spectrum of land uses from no change (the status quo) to complete conversion of the 1200 acres to native bottomland forest. Twenty-five criteria were used to measure the effects of each alternative over a 50-year period. Based on four different weighting schemes and transformed effects, the best alternatives were the agroforestry alternatives where a diverse mixture of forest and agricultural crops are produced. The evaluation strongly suggests that several land use options exist for Big Bear Hollow. These options represent alternatives that the Winnebago Tribe of Nebraska can choose from and can implement in order to achieve to a desired extent its diverse environmental, social, and economic objectives.

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AGROFORESTRY: PROMOTING SUSTAINABLE AGRICULTURE BY ENHANCING BIODIVERSITY[1]

Michele Schoeneberger[2] and Michael Dosskey[3]

INTRODUCTION

Agroforestry is being investigated as a means to enhance sustainability of modern high-input agricultural systems. At the Center for Semiarid Agroforestry, researchers are studying how to introduce trees and shrubs into farming systems in the central U.S. to simultaneously reduce the need for continual, intensive inputs of agricultural chemicals, conserve natural resources, and provide farmers with a more diverse economic base.

Agroforestry plantings are a flexible tool for enhancing diversity of agricultural systems. New species and habitats are added with each planting, and these can attract other species and their activities. Through planned selection of tree and shrub species for windbreaks, living snow fences, riparian buffer strips, and fuelwood plantations, we can promote ecological processes which may reduce the need for intensive inputs to adjacent agricultural fields. This agricultural concept has its foundation in the ecological concept of biological diversity.

BIOLOGICAL DIVERSITY

Biological diversity, or biodiversity, refers to the variety and complexity within ecological systems. Biodiversity encompasses variety in species, their genetic make-up, habitats, communities, and in the web of interactions and interrelated functions and processes that occur among them.

According to ecological theory, biodiversity imparts resiliency, stability, and sustainability to ecosystems. These qualities are derived from overlaps and redundancies in genes, species, habitats, and their functions and interactions which act to repair disturbances and rectify imbalances. For example, a niche vacated within an ecosystem is soon filled from within, thereby maintaining ecosystem integrity and function. Such processes are natural stabilizing mechanisms.

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[1]Paper presented at the U.S./Mexico Workshop on "Potentials for Agroforestry in Northern Mexico'; Saltillo, Coahuila, Mexico; April 12-15, 1994.

[2]Research Project Leader and Soil Scientist, USDA Forest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822.

[3]Research Ecologist, USDA Forest Service, Rocky Mountain Research Station, Center for Semiarid Agroforestry, East Campus - UNL, Lincoln, NE, USA 68583-0822.

Practices that enhance biodiversity in ecologically barren systems may be used to build more ecologically stable and sustainable systems.

MODERN HIGH-INPUT AGRICULTURE

Modern high-input agriculture is unparalleled in its ability to produce food and fiber. The quest for maximum crop yields, however, has resulted in biological simplification of agricultural landscapes. Today's large-scale agricultural system is based upon intensive cultivation of a limited number of species and varieties. For example, 90% of world food comes from just 15 plant and 8 animal species (Pimentel et al. 1992). Monoculture production, tillage, and weed, disease, and pest control are integral to attaining high yields, but severely reduce plant, animal, and soil biodiversity.

Production from high-input agricultural systems is difficult to sustain; requiring continual and massive inputs in the form of tillage, fertilizers, and pesticides. Longer-term sustainability depends upon future supply of external resources. Future supply and prices are uncertain under prevailing growing demand. Future effectiveness of inputs, such as pesticides, are also uncertain as pests continually develop resistance to them.

High-input practices also have persistent internal problems which reduce longterm sustainability. Soil erosion, water pollution, and loss of fish and wildlife habitat, continually reduce the resource basis of land productivity. At the same time, there is increasing public demand for the clean water and wildlife that agricultural land could provide.

Currently, there is a critical need in the U.S. for development of agricultural practices which reduce dependency on external resources, and instill a greater degree of sustainability to modern agricultural systems.

AGROFORESTRY: PROMOTING SUSTAINABILITY THROUGH BIODIVERSITY

In theory, more biologically diverse agricultural systems should be more stable and more easily sustainable. Agroforestry can be a useful tool for contributing a greater degree of sustainability to modern agriculture by enhancing the biological diversity of agricultural landscapes (Schoeneberger 1993).

The application of agroforestry for increasing agricultural sustainability requires making the right choices. It is unfeasible, if not impossible, to reconstruct the complexity of natural ecosystems. But, we <u>can</u> promote certain desirable qualities of them by adding the right kind of diversity to agriculture. We have control over the species composition and their arrangement, and some control over their location on the landscape, although in U.S. agriculture, agroforestry is normally limited to field margins.

The Center for Semiarid Agroforestry is investigating consequences of increased biodiversity resulting from the introduction of trees and shrubs to field margins. U.S. agroforestry practices normally target single purposes, such as windbreaks for better livestock and crop production, snow

fences for road protection, stream bank plantings for erosion control, riparian buffers for water pollution control, and plantations for wood products. These trees and shrubs incidentally introduce biodiversity benefits. Agroforestry plantings represent new habitats which attract a variety of wildlife and other organisms (Martin and Vohs 1982; Schroeder 1986). The Center in cooperation with the University of Nebraska is conducting research to understand biological interactions between agroforestry plantings and other organisms ranging from migratory birds to crop pests and their natural enemies. For example, preliminary studies have shown that field margins consisting of woody plants have more bird species, higher bird numbers, and more neotropical migrants than non-woody field margins (Fitzmaurice et al. 1994).

Of particular interest to us are organisms which can help control crop pests, i.e. biological control, or biocontrol, agents. Biocontrol is a well-known agricultural concept, and is a cornerstone of integrated pest management systems. Natural biocontrol agents can be used to control crop pests and reduce the need for pesticides, thereby increasing agricultural sustainability.

Studies have shown that the habitats created by field margin vegetation support a larger and more diverse population of natural pest enemies, such as birds and spiders, than monocultures (Dennis and Fry 1992). Field margin agroforestry plantings may provide breeding and living habitat, and alternative food sources for pest predators when abundance of crop pests are low (Dix 1991). An example of successful biocontrol through agroforestry is the practice of establishing prune trees and blackberry bushes around vineyards. These plantings become winter refuges for parasitic wasps which control the grape leafhopper, an economically important pest of grape crops (Altieri 1991).

To be effective biocontrol systems, agroforestry plantings must be designed with the right mix of plant species and landscape location. Proper habitat will attract biocontrol agents and provide conditions which will promote their populations. Care must be taken, however, to avoid constructing habitats which promote populations of pests. Riparian buffers may provide the greatest opportunity for providing biocontrol functions since riparian areas are potentially the most diverse and productive parts of the landscape.

Currently, researchers at the Center are investigating wildlife and biocontrol agents within normal agroforestry plantings. Eventually, they will consider design improvements which will attract and promote greater wildlife and biocontrol populations. The long-range implication for modern, high-input agriculture is greater biological diversity, and more sustainable agricultural ecosystems.

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AGROECOLOGY: AGRICULTURAL SYSTEMS, ENVIRONMENT, AND COMMUNITY[1]

Charles Francis[2]

Classical Approach to Ecology of Crops: Most traditional classes in agroecology have combined the two areas, agriculture and ecology, in a narrow and literal sense. They included the adaptation of individual crop species, environmental factors that influence productivity, and in some a survey of the world's cropping systems. There was often discussion nutrient and water cycles, integrated pest management, and of alternative tillage systems. If taught by an ecologist, the course included topics on evolution and domestication of plants, genetic resources, and ecological niches. Also included were dispersal and establishment of plants, mutualisms and species coexistence, diversity and stability, succession and productivity. Some courses dealt with management and alternative agricultural systems, including organic farming and biodynamic approaches. An example of such a course is Environmental Studies 130, given at U.C. Santa Cruz:

- ecology and agriculture, soil as an environmental factor
- water in the soil and atmosphere, temperature effects
- light, wind, and fire
- biotic factors, interference and environmental factors
- adaptation, evolution, domestication, managing genetic resources
- dispersal, establishment, ecological niches, island biogeography
- mutualisms, coexistence, interference, biological control, diversity
- disturbance, succession, structure, function, productivity
- agroecosystem management, alternatives for the future

In a classical treatment of agroecology, there has been limited or no reference to animal production, agroforestry, economics, management decisions, integrated systems, or impacts on the human community or quality of life. These topics have been incorporated into some of the more recent treatments of agroecology.

Biological and Social Approach to Agroecology: In contrast to the above course, a broader approach presupposes prior courses and some experience in ecology and the practical details of crop culture. This allows the instructors to move more quickly to broad issues and deal less with the specifics of crops and climate. Such a course could present more of the

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[1]Paper presented at the U.S./Mexico Workshop on "Potentials for Agroforestry in Northern Mexico"; Saltillo, Coahuila, Mexico; April 12-15, 1994.

[2]Director, Center for Sustainable Agricultural Systems and Professor of Agronomy, East Campus - UNL, Lincoln, NE, USA 68583-0910.

process of understanding agricultural ecosystems, research on components and systems, economics, and agricultural policy. An example of this type of course is one taught by a weed ecologist/systems agronomist and an agricultural economist, PSE 445 at University of Maine:

- agroecosystem analysis: rapid rural appraisal
- agroecosystem design, management examples, nutrient cycling
- social context of agroecosystems
- ecological insights from traditional farming systems
- on-farm versus on-station research
- participatory research models, farmer first approach
- agricultural technology and development
- indigenous knowledge and agricultural development
- biodiversity and agroecosystems
- cover crops and hedgerows
- green manuring and crop rotation
- vegetation diversity and insect pest management
- weed and pathogen management through diversity
- agroforestry systems
- agriculture, human values, and social structure
- industrialization of agriculture
- agricultural policy and sustainability
- socioeconomic aspects of sustainable agriculture

This course at University of Maine is "intended for upper level undergraduate and graduate students interested in technical, social, economic, and ethical components of sustainable farming systems." The instructors expect students to have completed a previous course in sustainable agriculture of have equivalent experience. These two examples of courses are among several now available in universities in the U.S. Curricula, course topics, and key references from a number of such courses are described in King and Francis (1994).

Importance of Agroecology, Components and Cycles: Agroecology brings together the components of designed agricultural systems and examines them more from the perspective of an ecological system with its complex interactions. It is still important to consider the resources needed for plant growth, the range of soils and climates in which crops are produced, and the natural and managed cycles that determine the productivity and success of a given system in a specific place and season. Some of the differences of research and cropping system design from an ecological perspective are the following, but represent only a sample of the large number of components that need to be studied:

- Evaluation of varieties and hybrids can be conducted across a range of environments and systems that most closely represent those in which the crops will be grown by farmers. Rather than carefully control all production resources and variables such as water (irrigation), soil nutrients (fertilizers), weeds, insects and pathogens (chemical pesticides), potential new cultivars can be tested on farms under the conditions that they will face when released to farmers. Traditional yield trials have included measurement of maturity, yield, and grain

moisture; a more in-depth approach could include total dry matter production, competitive ability with associated crops, production per day or per unit of most limiting resource, yield stability, and crop quality. Contributions of each promising cultivar to total system performance could be more important that absolute yield potential under ideal growing conditions.

- Research on crop response to soil nutrients has concentrated on applications of different rates of fertilizer and the resulting changes in crop grain yield. A more comprehensive agroecological approach would be to study the nutrient cycling within a cropping sequence and deal with the broad question of soil fertility rather than just applied fertilizer. Efficiency of nutrient uptake and use, conversion to carbohydrate and protein, alternative sources of plant nutrients such as animal or green manures, crop rotations, and intensive intercropping systems are all dimensions of the nutrient question that could be examined. Multiple sources of nutrients, their magnitude and use, and the fate of those nutrients within the system are dimensions of great importance if we are to understand cycles in the cropping environment. Contributions of animals integrated into the system need to be evaluated, as well as energy implications of alternative strategies.

- Pest management is far more than screening a range of pesticides and measuring their effects on weeds and crop yield. An information-intensive approach to pest management implies in-depth knowledge of locations and severity of infestations, information about alternative methods of control, levels of economic damage, and non-intended effects of control strategies. In-field crop diversity as well as crop rotations provide effective suppression of many pest species. Use of biological or mechanical control measures may qualify fields for organic certification, thus providing an added value to the harvested crops.

Importance of Agroecological Systems Analysis: More important that the studies of individual systems components, even though these are crucial elements of any production system, are the study and understanding of the many and complex interactions that occur among components of the system. The integration efficiencies that come with multiple species systems, with animals and crops working together, with diversity in agroforestry or permaculture systems provide new avenues for improved resource use and potential environmental soundness of agricultural production systems. There are also a number of alternative measures of success of systems that can be included in the analysis.

- Effects of system diversity in space (multiple species systems) and in time (crop rotations) give some clues to the potential productivity of carefully designed production systems. Many farmers use multiple cropping systems to more efficiently use total available resources, to buffer the biological productivity and economic returns of systems under unpredictable and variable climatic and market conditions, or to provide a range of food for consumption and products for sale. Crop

rotations are effective in controlling or suppressing many insect and weed problems, and can be combined with other ecologically sound techniques to reduce or eliminate chemical pesticides from the system.

- Crop/animal integration on the farm provides some biological and economic efficiencies not available to farmers with only specialized enterprises. Animals can consume raw or processed grain and forage produced on the farm, and can often use grain or residues that are unsalable through normal channels. Grazing maize residue with ruminants is an example in the midwest U.S. Livestock provide a way to add value to what are often low-value feed grains. The grain farmer is subject to variations in local and overseas markets, uncertain subsidies from government programs, fluctuations in international currencies, and political decisions far beyond the farm gate. Many sustainable farms include a livestock component.

- Evaluation of system output has traditionally been in tons/ha of grain or economic net return/ha, with limited regard for other measures of productivity or success. Yield per unit of the most limiting resource -- a specific nutrient, unit of water, unit of energy, unit of capital, hour of labor -- may be more important than return/ha in some circumstances. Energy efficiency of a total production system can be enhanced by reduction of fossil fuel inputs and substitution of management or information that goes into system design. Environmental impact of systems is rarely measured, unless there is a specific report of damages to property or flagrant impact of chemicals that reach an unintended target. There is a need for more comprehensive measures of system success, and agroecology provides a route to develop them.

Other Contributions of Agroecology: Principles of ecology can make substantial contributions to the understanding of natural processes in agricultural systems and give guidance on measuring performance or designing new combinations for the future. Better information about nutrient flows through the system, pest dynamics in the field and in a larger area, microbiological interactions in the soil, and allelopathic effects of crops in sequence can contribute to more efficient system design. Understanding ecological niches and nutrient/water use by different species in natural systems can lead to design of environmentally sound multiple cropping systems. The broad issues included in the course outline from University of Maine demonstrate both the complexity and the potentials of studying and evaluating agroecosystems that include management and human goals as part of the equation. These are emerging dimensions of agroecology, pioneered in part by CLADES in Latin America, a group that identifies sustainable development as a key issue.

Summary and Other Information Resources: These are only a few of the dimensions of agroecology and how systems can be studied in their entirety, rather than as discrete components. The human dimension of agricultural systems is the newest addition to the study of agroecosystems, and this is being approached as a critical element of sustainable agricultural development.

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SUSTAINABLE DEVELOPMENT: OPPORTUNITIES FOR COOPERATION[1]

Charles Francis[2]

The term sustainable development has come into popular usage over the past several years, and especially since the meeting of the United Nations Conference on Sustainable Development in Brazil in 1992. The four volume report from this meeting on Agenda 21 contains details from the many group meetings at the conference and the resolutions and action agenda that has since been adopted by many nations. Such influential agencies as the World Bank and the U.S. Agency for International Development routinely use this language to describe the goals and strategies of new projects they finance. Just as with sustainable agriculture, there are many definitions of sustainable development.

The overwhelming needs of the world's peoples and the foundation for cooperation are stated in the preamble to Agenda 21 (Robinson, 1993). "Humanity stands at a defining moment in its history. We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our well-being. However, integration of environment and development concerns, and greater attention to them, will lead to the fulfillment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future. No nation can achieve this on its own; but together we can - in a global partnership for sustainable development."

Conventional Development Agenda: The neoclassical economic model that has dominated Western thought and national policy making since the start of the industrial revolution has defined progress in terms of growth. This has been interpreted as increase in gross national product, growth in per capita income, or some similar measure of quantitative increase in family or community wealth or material possessions. Results of most agricultural research or the production from a farm are measured in tons/hectare, or economically as net return per hour of labor or per hectare. Factory productivity likewise is measured in units manufactured, returns to capital investment or labor, or monetary returns to management. Without growth, a country or a sector of its economy is said to be 'stagnant', losing ground to inflation, or generally falling behind in an increasingly competitive world.

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[2]Director, Center for Sustainable Agricultural Systems and Professor of Agronomy, East Campus - UNL, Lincoln, NE, USA 68583-0910.

The high cost of this dominant agricultural and economic development paradigm is only now becoming apparent to a growing segment of the population. The extractive economy is built on a mining mentality that exploits natural resources in the short term while passing on the real costs and shortages in resources to later generations. Some call this mortgaging the future in favor of economic gains in the present. Such a strategy is short-sighted and ultimately destructive. It ignores the 'wisdom of the elders' that was closely followed by the Lakota Sioux, a native American group in the Northern Great Plains, who believed that any important decision should be considered in terms of its impact over the next seven generations. That is about 200 years, and represents a forward thinking that is foreign to our current dominant cultures.

An Evaluation of Goals: There is an emerging appreciation of the shortsightedness of the current development paradigm. We now realize that the model of the U.S., Western Europe, and a few other areas, with an extremely high current level of consumption of goods and services and ultimately the natural resources on which they depend, can only be available to a small fraction of the world's population. It is not only an unattainable goal for most of the world's poor, but is not even sustainable in these few areas with a high current standard of living over the long term. With growing concern about the global equity of resource use, availability of food, health care and education, and opportunities for future development, many thoughtful people are challenging the current predominant goals of society and are seeking new strategies for global survival of our species. A comprehensive set of these goals is outlined in Agenda 21, and can be summarized as follows:

- goals for an international economy
  -promote sustainable development through trade liberalization
  -make trade and environmental quality mutually supportive
  -provide adequate financial resources to developing countries
  -find macroeconomic policies to improve the environment

- goals to combat poverty
  -provide all persons with opportunity to earn a sustainable livelihood
  -promote income generation for all, local institutions and control
  -develop integrated strategies for poverty stricken areas
  -create investment in human capital, for poor, rural people, and women

- goals to change consumption patterns
  -promote patterns that reduce environmental stress and meet basic needs
  -develop more sustainable consumption patterns

- goals in human demographics
  -understand population trends and factors in the global analysis of environment
  -learn about demographic dynamics, technology, cultural behavior, natural resources
  -understand balance between people, resources and life support systems

-assess human vulnerability in ecologically sensitive areas and set priorities

- goals in promoting and protecting human health
  -meet primary health needs, especially in rural areas and for poor people
  -control communicable diseases
  -protect vulnerable groups, malnourished, poor, women, children
  -meet the urban health challenges

- goals for sustainable human settlements
  -provide adequate shelter for all people under a wide range of conditions
  -improve human settlement management
  -promote sustainable land use planning and management
  -promote clean water, sanitation, drainage, solid waste management
  -promote settlement planning in disaster prone areas
  -promote sustainable construction industry activities
  -promote human resource development and capacity building

- goals for integrating environmental concerns in decision making
  -integrate environmental issues into policy, planning and management
  -provide effective legal and regulatory framework for sound decisions
  -make effective use of markets and other incentives
  -establish systems for integrated environmental accounting

- goals for protection of the atmosphere
  -address uncertainties and scientific basis for decisions
  -prevent stratospheric ozone depletion
  -address transboundary atmospheric pollution

- goals for planning and management of land resources
  -develop policies for best possible use of land
  -improve and strengthen planning and management of land

- goals for combatting deforestation
  -strengthen forest-related national institutions and planning develop sustainable strategies for use of forest resources

- goals for managing fragile ecosystems
  -monitor decertification and drought and plan for alternative land use
  -strengthen regional and global information systems
  -monitor decertification and improve living conditions in affected areas
  -understand fragile mountain ecosystems and reduce environmental degradation

- goals for sustainable agriculture and development
  -integrate environmental concerns with policy decisions
  -enhance sustainable food production and food security
  -improve countries' capacities to develop food policies and strategies

- goals for preserving biological diversity
  -develop national and international strategy for conservation
  -assure the fair and equitable sharing of biological resources
  -study methods of preservation of biological diversity
  -recognize needs of indigenous peoples and their use of genetic resources
  -improve development of biotechnology to conserve diversity

- goals for sustainability of oceans
  -assure marine environmental protection
  -develop sustainable use and conservation of marine biodiversity
  -promote integrated and sound management of coastal areas
  -improve international cooperation for conservation
  -promote sustainable development of islands

- goals for preserving freshwater resources
  -develop water assessment methods and management strategies
  -protect water resources, quality, and aquatic systems
  -define water use for sustainable food production and development
  -assess the impact of global climate change on water resources

- goals for equitable involvement of women in development
  -enhance participation of women in national ecosystem management
  -increase proportion of women decision makers and planners
  -develop a strategy to eliminate constitutional, legal or other obstacles
  -assure women's participation in education
  -assure access to all opportunities in employment and services in all societies
  -assure women's rights in determining number and spacing of children
  -prohibit violence against women through educational and legal means

Opportunities for Cooperation: The Agenda 21 meeting produced a clear set of signals that these challenges on a global scale cannot be met by any small group of visionaries nor by any country working alone. Although it will be difficult to establish an action agenda on a world-wide scale, the task can begin where we recognize specific challenges on the local level and begin to foster an awareness and resolve to make changes in our societies and institutions to seek a more desirable future. Wes Jackson, Director of The Land Institute in Salina, Kansas, urges us to establish 'a sense of place.' He suggests that until we understand the true nature of each place and strive to work within the natural resources and confines of that place, we will be unable to create a truly sustainable human community. Our place is the Great Plains, and the national and state boundaries that cross this place are both arbitrary and artificial, at least from an ecological and environmental point of view. We need to seek solutions that are biologically sound, environmentally friendly, and socially acceptable for the people who live in this place. Agroforestry systems that are unique to the farms and ranches in the Southern Great Plains in Mexico and the U.S. can be developed through joint educational and research activities. International funding is apparently forthcoming to make this a reality.

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